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OF THE

FOURTH ANNUAL ACQUISITION RESEARCH SYMPOSIUM WEDNESDAY SESSIONS VOLUME I

Acquisition Research:

Creating Synergy for Informed Change

May 16-17, 2007

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ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL

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The research presented at the symposium was supported by the Acquisition Chair of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

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Copies of the Acquisition Sponsored Research Reports may be printed from our website www.acquisitionresearch.org

Conference Website:
www.researchsymposium.org

Preface and Acknowledgements

Founded in 2003, the Acquisition Research Program (ARP) has become an institutional, multi-disciplinary entity. In 2006 the ARP made significant and sustaining progress toward realizing its goals to:

1. **Position NPS as a recognized leader in defense acquisition research.**

2. **Establish NPS acquisition research as an integral part of policy-making for Department of Defense officials.**

3. **Create a stream of relevant information concerning the performance of DoD Acquisition policies with viable recommendations for continuous process improvement.**

4. **Prepare the DoD workforce to participate in the continued evolution of the defense acquisition process.**

5. **Collaborate with other universities, think tanks, industry and government in acquisition research.**

Since inception, over 100 reports and papers have been published, thereby making a significant contribution to the body of literature on the defense acquisition process. Through these research products, ARP sponsors are receiving substantial help with and insights into the pressing business issues of the day.

The synergy between faculty research and student classroom instruction has been exceptional with many relevant and current instructional materials emerging from research products, thus enhancing the student educational experience. Faculty are “refreshed” in defense-relevant subject matter, and students are better prepared to enter the acquisition work force. In recognition of these successes, the Under Secretary of Defense for Acquisition, Technology and Logistics (USD (AT&L)) provided $1M in funding for additional projects. This funding expands the ARP by 30% and is a pilot for future increases in research funding.

Researcher opportunities provided by the Chair offer significant benefits to researchers: (1) provision of funding saving researchers “marketing“ time; (2) ties with sponsor POCs thus assuring DOD relevant research; (3) assistance with final formatting, editing and publishing thus relieving researchers from the “non-intellectual” aspects of their research. Each of these is a substantial benefit but the growing connectivity between researchers and sponsors is paying large dividends to all concerned. While we at the Naval Postgraduate School like to think of our institution as the world’s leader in defense acquisition research, we also recognize that, because of our limited size and resources, we are able to study only a few of acquisition’s myriad of complex issues and challenges. We know that genuine progress in acquisition research can be achieved and sustained only to the extent that scholars from a broad range of institutions and disciplines are engaged to participate. Once this “critical mass” of researchers is formed, we may anticipate that acquisition will become a field of its own, with perhaps a variety of acquisition journals, acquisition conferences, and university courses in acquisition management and policy. Such intellectual capacity, we may hope, will before long prevail against acquisition’s perennial and often pernicious problems.

Accordingly, the year 2006 was especially significant for the NPS Acquisition Research Program in taking major strides toward expanding the program's reach in important ways to other institutions. The number of research institutions participating as collaborators grew to 35 with the formation of a Virtual University Consortium. Most noteworthy was, as mentioned above, our securing sponsorship from USD(AT&L) to fund research proposals selected from a nationwide call, or Broad Agency Announcement (BAA) (copy available at www.acquisitionresearch.org). We're truly excited at the prospects of receiving innovative and cutting edge proposals from the top minds around the country. We trust that this new sponsorship will act like good seeds sown in fertile soil, yielding rich fruits of profitable acquisition research for many years to come.

We gratefully acknowledge the ongoing support and leadership of our sponsors, whose foresight and vision have assured the continuing success of the Acquisition Research Program:

- Under Secretary of Defense (Acquisition, Technology and Logistics)
- Assistant Secretary of the Navy (Research, Development and Acquisition)
- Program Manager (Infantry Combat Equipment)
- Program Executive Officer (Integrated Warfare Systems)
- Program Executive Officer (Littoral and Mine Warfare)
- Project Manager (Modular Brigade Enhancements)
- Program Executive Officer (Ships)
- Dean of Research, Naval Postgraduate School

We also thank UGS Corporation and the Naval Postgraduate School Foundation and acknowledge their generous contributions in support of this symposium.

James B. Greene, Jr.	Keith F. Snider, PhD
Rear Admiral, US Navy (ret)	Associate Professor

The NPS “A Team”

Rear Admiral James B. Greene, Jr. USN (Ret.) — Acquisition Chair, Naval Postgraduate School. RADM Greene develops, implements and oversees the Acquisition Research Program in the Graduate School of Business and Public Policy. He interfaces with the DoD, industry and government leaders in acquisition, supervises student MBA projects and conducts guest lectures and seminars. Before serving at NPS, RADM Greene was an independent consultant focusing on Defense Industry business development strategy and execution (for both the public and private sectors), minimizing lifecycle costs through technology applications, alternative financing arrangements for capital-asset procurement, and “red-teaming” corporate proposals for major government procurements.

RADM Greene served as the Assistant Deputy Chief of Naval Operations (Logistics) in the Pentagon from 1991-1995. As Assistant Deputy, he provided oversight, direction and budget development for worldwide US Navy logistics operations. He facilitated depot maintenance, supply-chain management, base/station management, environmental programs and logistic advice and support to the Chief of Naval Operations. Some of his focuses during this time were leading Navy-wide efforts to digitize all technical data (and, therefore, reduce cycle time) and to develop and implement strategy for procurement of eleven Sealift ships for the rapid deployment forces. He also served as the Senior Military Assistant to the Under Secretary of Defense (Acquisition) from 1987-1990 where he advised and counseled the Under Secretary in directing the DoD procurement process.

From 1984-1987, RADM Greene was the Project Manager for the Aegis project. This was the DoD’s largest acquisition project with an annual budget in excess of $5 Billion/year. The project provided oversight and management of research, development, design, production, fleet introduction and full lifecycle support of the entire fleet of Aegis cruisers, destroyers and weapons systems through more than 2500 industry contracts. From 1980-1984, RADM Greene served as Director, Committee Liaison, Office of Legislative Affairs followed by a tour as the Executive Assistant, to the Assistant Secretary of the Navy (Shipbuilding and Logistics). From 1964-1980, RADM Greene served as a Surface Warfare Officer in various duties, culminating in Command-at-Sea. His assignments included numerous wartime deployments to Vietnam as well as the Indian Ocean and the Persian Gulf.

RADM Greene received a BS in Electrical Engineering from Brown University in 1964; he earned a MS in Electrical Engineering and a MS in Business Administration from the Naval Postgraduate School in 1973.

Keith F. Snider — Associate Professor of Public Administration and Management in the Graduate School of Business & Public Policy at the Naval Postgraduate School in Monterey, California, where he teaches courses related to defense acquisition management. He also serves as Principal Investigator for the NPS Acquisition Research Program and as Academic Associate for resident NPS acquisition curricula.

Professor Snider has a PhD in Public Administration and Public Affairs from Virginia Polytechnic Institute and State University, a Master of Science degree in Operations Research from the Naval Postgraduate School, and a Bachelor of Science degree from the United States Military Academy at West Point. He served as a field artillery officer in the US Army for twenty years, retiring at the rank of Lieutenant Colonel. He is a former member of

the Army Acquisition Corps and a graduate of the Program Manager's Course at the Defense Systems Management College.

Professor Snider's recent publications appear in *American Review of Public Administration*, *Administration and Society*, *Administrative Theory & Praxis*, *Journal of Public Procurement*, *Acquisition Review Quarterly*, and *Project Management Journal.*

Karey L. Shaffer — Program Manager for the Acquisition Research Program at the Graduate School of Business and Public Policy, Naval Postgraduate School. As PM, Shaffer is responsible for operations and publications in conjunction with the Acquisition Chair and the Principal Investigator. She has also catalyzed, organized and managed the Acquisition Research Symposiums hosted by NPS.

Shaffer has also served as an independent Project Manager and Marketing Consultant on various projects. Her experiences as such were focused on creating marketing materials, initiating web development, assembling technical teams, managing project lifecycles, processes and cost-savings strategies.

From 2001-2002, Shaffer contracted to work as the Executive Assistant to the Vice President for Leadership and Development Human Resources for Metris Companies in Minneapolis. In this capacity, she introduced project lifecycle and process improvements to increase efficiency. Likewise, as a Resource Specialist contractor at Watson Wyatt Worldwide in Minneapolis, she developed and implemented template plans to address continuity and functionality in corporate documents; in this same position, she introduced process improvements to increase efficiency in presentation and proposal production in order to reduce the instances of corruption and loss of vital technical information.

Shaffer has also served as the Project Manager for Imagicast, Inc. and as the Operations Manager for the Montana World Trade Center. At Imagicast, she was asked to take over the project management of four failing pilots for Levi Strauss in the San Francisco office. Within four months, the pilots were released; the project lifecycle was shortened; and the production process was refined. In this latter capacity at the MWTC, Shaffer developed operating procedures, policies and processes in compliance with state and federal grant law. Concurrently, she managed $1.25 million in federal appropriations, developed budgeting systems and secured a $400,000 federal technology grant. As the Operations Manager, she also designed MWTC's Conference site, managed various marketing conferences, and taught student practicum programs and seminars.

Shaffer has her BA in Business Administration (focus on International Business, Marketing and Management) from the University of Montana. She is currently earning her MBA from San Francisco State University.

A special thanks to our editor Jeri Larsen for all that she has done to make this publication a success, to David Wood and Carl Matsen for production, to Ian White for graphic support, to Lindsay D'Penha for CD programming, to Jordy Boom for conference website development. We would like acknowledge Arlene Pulido, Jennifer Watson, Bon Troung, Toan Tran and Jason Munoz of the staff at the Graduate School of Business & Public Policy for all the administrative support on the backend to make the Symposium a success. Our program success is directly related to the combined efforts of many.

ACQUISITION RESEARCH:

CREATING SYNERGY FOR INFORMED CHANGE

5th Annual Acquisition Research Symposium

May 14 - 15, 2008

Monterey, California

Announcement and Call for Proposals

The Graduate School of Business & Public Policy at the Naval Postgraduate School announces the **5th Annual Acquisition Research Symposium** to be held **May 14-15, 2008 in Monterey, California.**

This symposium serves as a forum for the presentation of acquisition research and the exchange of ideas among scholars and practitioners of public-sector acquisition. We seek a diverse audience of influential attendees from academe, government, and industry who are well placed to shape and promote future research in acquisition.

The Symposium Program Committee solicits proposals for panels and/or papers from academicians, practitioners, students and others with interests in the study of acquisition. The following list of topics is provided to indicate the range of potential research areas of interest for this symposium: **acquisition and procurement policy, supply chain management, public budgeting and finance, cost management, project management, logistics management, engineering management, outsourcing, performance measurement, and organization studies.**

Proposals must be submitted by **November 9, 2007**. The Program Committee will make notifications of accepted proposals by **December 7, 2007**. Final papers must be submitted by **April 4, 2008** to be included in the Symposium Proceedings.

Proposals for papers should include an abstract along with identification, affiliation, and contact information for the author(s). Proposals for papers plan for a 20 minute presentation. Proposals for panels (plan for 90 minute duration) should include the same information as above as well as a description of the panel subject and format, along with participants' names, qualifications and the specific contributions each participant will make to the panel.

Submit paper and panel proposals to www.researchsymposium.org **.**

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NPS BAA-07-002

BROAD AGENCY ANNOUNCEMENT

Acquisition Research Program

Naval Postgraduate School

Open until 4:00 pm PDST 1 June 2007

Primary objective is to attract outstanding researchers and scholars to investigate topics of interest to the defense acquisition community. The program solicits innovative proposals for defense acquisition management and policy research to be conducted during fiscal year (FY) 2008 (1 Oct 07 -30 Sep 08).

Defense acquisition management and policy research refers to investigations in all disciplines, fields, and domains that (1) are involved in the acquisition of products and/or services for national defense, or (2) could potentially be brought to bear to improve defense acquisition. It includes but is not limited to economics, finance, financial management, information systems, organization theory, operations management, human resources management, and marketing, as well as the "traditional" acquisition areas such as contracting, program/project management, logistics, and systems engineering management.

This program is targeted in particular to U.S. universities (including U.S. government schools of higher education) or other research institutions outside the Department of Defense.

The Government anticipates making multiple awards up to $100,000 each for a basic research period of twelve months. NPS plans to complete proposal evaluations and notify awardees in early August 2007.

Full Text for NPS BAA-07-002

at

http://www.nps.edu/Research/WorkingWithNPS.html

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Disclaimer: The views represented in this report are those of the authors and do not reflect the official policy position of the Navy, the Department of Defense, or the Federal Government.

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Wednesday, May 16, 2007

Keynote Speaker

Wednesday, May 16, 2007	**Keynote Speaker**
8:00 a.m. – 9:15 a.m.	**Keynote Speaker** **The Honorable Delores M. Etter** – Assistant Secretary of the Navy for Research, Development and Acquisition

The Honorable Delores M. Etter, Assistant Secretary of the Navy for Research, Development and Acquisition, was nominated on September 6, 2005 by President George W. Bush to serve as the Assistant Secretary of the Navy for Research, Development and Acquisition. Dr. Etter was then sworn in on November 7, 2005. As the Navy's Senior Acquisition Executive, Dr. Etter is responsible for research, development, and acquisition within the Department of the Navy. From August 2001 to November 2005, Dr. Etter was a member of the Electrical Engineering faculty at the United States Naval Academy. She was also the first recipient of the Office of Naval Research Distinguished Chair in Science and Technology. Her academic interests were in digital signal processing and communications. Her research interests included biometric signal processing, with an emphasis on identification using iris recognition. She has also written several textbooks on computer languages and software engineering.

From June 1998 through July 2001, Dr. Etter served as the Deputy Under Secretary of Defense for Science and Technology. In that position, she was responsible for Defense Science and Technology strategic planning, budget allocation, and program execution and evaluation for the DoD Science and Technology Program. Dr. Etter was the Principal U.S. representative to the NATO Research and Technology Board. She was also responsible for the Defense Modeling and Simulation Organization, the High Performance Computing Modernization Office, and for technical oversight of the Software Engineering Institute. Dr. Etter was also the senior civilian in charge of the DoD high-energy laser research program.

From 1990-98, Dr. Etter was a Professor of Electrical and Computer Engineering at the University of Colorado, Boulder. During 1979-89, Dr. Etter was a faculty member in Electrical and Computer Engineering at the University of New Mexico. She served as Associate Vice President for Academic Affairs in 1989. During the 1983-84 academic year she was a National Science Foundation Visiting Professor in the Information Systems Laboratory in the Electrical Engineering Department at Stanford University.

Dr. Etter is a member of the National Academy of Engineering. She is also a former member of the National Science Board and the Defense Science Board. She is a Fellow of the Institute of Electrical and Electronic Engineers (IEEE), the American Association for the Advancement of Science (AAAS), and the American Society for Engineering Education (ASEE). She served as President of the IEEE Acoustics, Speech, and Signal Processing Society from 1988-89, and was Editor-in-Chief of the IEEE Transactions on Signal Processing from 1993-95.

Dr. Etter was a member of the Naval Research Advisory Committee from 1991-97, and chaired the committee from 1995-97. She has received the Department of the Navy Distinguished Public Service

Award, the Secretary of Defense Outstanding Public Service Medal, and the Department of Defense Distinguished Public Service Medal.

Panel 1 - Plenary Panel - Acquisition Reform

Wednesday, May 16, 2007	**Panel 1 - Plenary Panel - Acquisition Reform**
9:30 a.m. – 11:00 a.m.	**Chair:** **Jacques S. Gansler**, Director, Center for Public Policy & Private Enterprise, University of Maryland, former Under Secretary of Defense for Acquisition, Technology and Logistics **Discussants:** **William C. Greenwalt**, Deputy Under Secretary of Defense for Industrial Policy, Office of the Under Secretary of Defense (Acquisition, Technology and Logistics) **Robert H. Trice**, Senior Vice President, Business Development, Lockheed Martin Corporation **Pierre Chao**, Senior Fellow and Director of Defense Industrial Initiatives, Center for Strategic and International Studies

Chair: Jacques S. Gansler, former Under Secretary of Defense for Acquisition, Technology and Logistics, is the first holder of the Roger C. Lipitz Chair in Public Policy and Private Enterprise. As the third ranking civilian at the Pentagon from 1997 to 2001, Professor Gansler was responsible for all research and development, acquisition reform, logistics, advanced technology, environmental security, defense industry, and numerous other security programs. Before joining the Clinton Administration, Dr. Gansler held a variety of positions in government and the private sector, including Deputy Assistant Secretary of Defense (Material Acquisition), Assistant Director of Defense Research and Engineering (Electronics), Vice President of ITT, and engineering and management positions with Singer and Raytheon Corporations. Throughout his career, Dr. Gansler has written, published and taught on subjects related to his work. He is the author of *Defense Conversion: Transforming the Arsenal of Democracy*, MIT Press, 1995; *Affording Defense*, MIT Press, 1989, and *The Defense Industry*, MIT Press, 1980. He has published numerous articles in *Foreign Affairs*, *Harvard Business Review, International Security*, *Public Affairs*, and other journals as well as newspapers and frequent Congressional testimonies. He is a member of the National Academy of Engineering and a Fellow of the National Academy of Public Administration.

Discussant: William C. Greenwalt, Deputy Under Secretary of Defense for Industrial Policy, Office of the Under Secretary of Defense (Acquisition, Technology and Logistics), is the principal advisor to the Under Secretary of Defense (Acquisition, Technology & Logistics) and the Deputy Under Secretary of Defense (Acquisition and Technology) on all matters relating to the defense industrial base. His office is responsible for ensuring that DoD policies, procedures, and actions stimulate and support vigorous competition and innovation in the industrial base supporting defense; and establish and sustain cost-effective industrial and technological capabilities that assure military readiness and superiority.

Prior to joining DoD, Mr Greenwalt was a Professional Staff Member of the Senate Armed Services Committee (Senator John Warner, Chairman) from March 1999 until March 2006 and was responsible for defense acquisition policy, industrial base, export control, and management reform issues. In addition, from January 2004, he served as deputy to the staff director and provided oversight and management direction of the committee's legislative activities. He was also a lead staff

member for the Subcommittee on Readiness and Management Support and the Subcommittee on Strategic Forces. Previously, he served on the Senate Governmental Affairs Committee (Senator Fred Thompson, Chairman) as a Professional Staff Member responsible for federal management issues and committee press relations.

Mr Greenwalt also served as a staff member for the Senate Subcommittee on Oversight of Government Management (Senator William Cohen, Chairman) where he was responsible for legislative efforts to reform federal information technology acquisition culminating in the Clinger-Cohen Act of 1996. Prior to coming to the Senate in 1994, Mr Greenwalt was a visiting fellow at the Center for Defense Economics, University of York, England, worked for the Immigration and Naturalization Service in Frankfurt, Germany and served as an evaluator with the US General Accounting Office in Los Angeles, California where he specialized in defense acquisition issues.

Mr Greenwalt graduated from California State University at Long Beach in 1982 with a degree in political science and economics and received his MA in defense and security studies from the University of Southern California in 1989. He is married to Paula Mathews and they live with their son, Geoffrey, and daughter Jenna, in Arlington, VA.

Discussant: Pierre Chao is a Senior Fellow and Director of Defense Industrial Initiatives, Center for Strategic and International Studies. Before joining CSIS in 2003, Pierre was a managing director and senior aerospace/defense analyst at Credit Suisse First Boston from 1999-2003, where he was responsible for following the U.S. and global aerospace/defense industry. He remained a CSFB independent senior adviser from 2003-2006.

Prior to joining CSFB, Pierre was the senior aerospace/defense analyst at Morgan Stanley Dean Witter from 1995-1999. He served as the senior aerospace/defense industry analyst at Smith Barney during 1994 and as a director at JSA International, a Boston/Paris-based management-consulting firm that focused on the aerospace/defense industry (1986-88, 1990-93). Pierre was also a co-founder of JSA Research, an equity research boutique specializing in the aerospace/defense industry. Before signing on with JSA, he worked in the New York and London offices of Prudential-Bache Capital Funding as a mergers and acquisitions banker focusing on aerospace/defense (1988-90).

Pierre garnered numerous awards while working on Wall Street. Institutional Investor ranked Pierre's team the number one global aerospace/defense group every year eligible from 2000-02 and he was on the Institutional Investor All-America Research Team every year eligible from 1996-2002. He was ranked the number one aerospace/defense analyst by corporations in the 1998-2000 Reuters Polls, the number one aerospace/defense analyst in the 1995-99 Greenwich Associates polls, and appeared on the Wall Street Journal All-Star list in four of seven eligible years.

In 2000, Pierre was appointed to the Presidential Commission on Offsets in International Trade. He was a member of the 2005 Defense Science Board Summer Study (Assessment of Transformation), 2006 DSB Summer Study (Strategic Technology Vectors), and the 2006/2007 DSB Task Force on the Health of the Defense Industry. He is also a guest lecturer at the National Defense University and the Defense Acquisition University. Pierre has been sought out as an expert analyst of the defense and aerospace industry by the Senate Armed Services Committee, the House Science Committee, Office of the Secretary of Defense, DoD Defense Science Board, Army Science Board, NASA, DGA (France), NATO and the Aerospace Industries Association Board of Governors.

Pierre earned dual Bachelor of Science degrees in Political Science and Management Science from M.I.T.

Panel 2 – Crossing the Valley of Death: Technology Transition

Wednesday, May 16, 2007 11:15 a.m. – 12:45 p.m.	**Panel 2 – Crossing the Valley of Death: Technology Transition**
	Chair: **John J. Kubricky**, Deputy Under Secretary of Defense (Advance Systems and Concepts) **Discussant:** **Allan Shaffer**, Director, Plans Programs and Office, Director Defense Research and Engineering **Papers:** ***Stronger Practices Needed to Improve DoD Technology Transition Practices*** **Michael Sullivan**, US Government Accountability Office ***Crossing the Technology Transfer Chasm: Network Externalities, Coordination Games and Lessons Learned from ACTDs*** **Peter Coughlan, Nicholas Dew** and **William (Bill) Gates**, Naval Postgraduate School ***Development vs. Deployment: How Mature Should a Technology Be before It Is Considered for Inclusion in an Acquisition Program?*** **Michael J. Pennock, William B. Rouse** and **Diane L. Kollar**, Tennenbaum Institute, Georgia Institute of Technology

Chair: John J. Kubricky, Deputy Under Secretary of Defense (Advanced Systems and Concepts), has oversight responsibilities for technology transition and transfer programs to include: Advanced Concept and Joint Capability Technology Demonstrations, Joint Warfighting Program, Foreign Comparative Test, Defense Acquisition Challenge, Technology Transition Initiative, ManTech, Defense Production Act Title III, Dual Use S&T, Independent Research and Development, and TechLink.

Prior to taking this position in October, 2006, Mr. Kubricky was the Department of Homeland Security's Director of Systems Engineering and Development with the Science & Technology Directorate. Mr. Kubricky's primary responsibility was to integrate proven technologies into systems for demonstration, operational test and evaluation, and pre-production prototypes, which adaptation and deployment of military technologies for homeland security applications. He had also served as the Homeland Security Advanced Research Projects Agency's (HSARPA) acting director since July 2005, where more than 100 advanced technology programs were managed by the agency under contracts with the private sector. HSARPA initiatives include a Small Business Innovative Research (SBIR) program, Technology Transfer, and Rapid Technology Application Program, each of which transitioned new security technologies to operational customers.

Before his service in the Federal government, Mr. Kubricky's career in industry was as a prime systems integrator of tactical intelligence systems on airborne, ground and marine platforms. He is credited with designing, integrating and fielding the US Army's first multi-sensor aircraft; for developing real-time multi-sensor fusion work-stations that became a baseline for today's tactical intelligence processing systems; and for prototypes of Unmanned and Optionally Piloted Airborne Vehicles, which achieved over 25,000 flight hours in world-wide deployments. In addition to innovations in tactical intelligence programs, Mr. Kubricky is a veteran program manager of strategic reconnaissance development, manufacturing and test/evaluation programs.

Mr. Kubricky holds a Bachelor of Science degree from Johns Hopkins University, where he also attended the graduate program for Industrial Management. Mr. Kubricky's service with the US Army includes a tour with the Ninth Infantry Division in Vietnam during 1968 and 1969. He and his wife Joy, have one son, and live in Maryland.

Discussant: Allan Shaffer, Director, Plans Programs and Office, Director Defense Research and Engineering, is responsible for budget and planning oversight of the entire Department of Defense Science and Technology Program. Mr. Shaffer earned a Bachelor of Science Degree in Mathematics from the University of Vermont in 1976, and was commissioned in the United States Air Force. He was then assigned to the University of Utah, where he earned a second Bachelor of Science Degree in Meteorology. He also earned a Master of Science in Meteorology from the Naval Postgraduate School (with distinction).

He then had a number of assignments in weather, intelligence, and science and technology management. He was assigned to Mather AFB, Sacramento, California, as the Wing Weather Officer to the 323d Flying Training Wing and the 320th Bombardment Wing (Heavy). In 1984, he was assigned to the Foreign Technology Division (FTD), where he was an intelligence analyst and staff meteorologist, assessing the technical capabilities of the Former Soviet Union, as well as the performance of Soviet weapons systems, including assessment of the impact of the atmosphere on Soviet military laser systems. While at Wright-Patterson, Mr. Shaffer had an extended temporary duty as officer in charge, Weather Support Force, Palmerola Air Base, Honduras. He was also named Air Weather Service Junior Officer of the Year.

From Ohio, he became Commander, Detachment 2, 7th Weather Squadron, Hanau, Germany, providing all weather support to the 3rd Armored Division, then Chief, Plans and Programs at the 5th Weather Wing, Langley Air Force Base, Virginia. In this position, Mr. Shaffer was responsible for all combat support plans and financial matters for approximately 50 weather units assigned to Air Combat Command and the US Army Forces Command. Additionally, he planned and integrated technology capabilities from defense laboratories into operations. From Langely, in 1993, he was assigned to the Industrial College of the Armed Forces, Ft. McNair, D. C., where he was awarded a Master of Science in National Resource Management.

Next, he was assigned to Hq Air Force, with assignments as Chief, Plans Division; Chief Interagency Affairs; and Chief, Resources Division, USAF Directorate of Weather. In these positions, he planned and assigned resource allocation for existing and future Air Force systems. In 1996, he was assigned as Specialist for Battlespace Environments, Defense Research and Engineering. In this position, he was responsible for oversight of the DoD technology base programs in Oceanography, Terrain and Topography, Meteorology and Space Physics. In 1998, he became the Military Assistant to the Deputy Under Secretary of Defense (Science and Technology)

In 1999, he took his last military position as Director, Plans and Programs, Air Force Weather Agency, Offutt AFB, Nebraska. Upon retirement from active military duty in 2000, he returned to the Pentagon as a career civil servant and became Director, Multi-Disciplinary Systems, Office of the Deputy Under Secretary of Defense for Science and Technology. He assumed his current position in March 2001.

Stronger Practices Needed to Improve DoD Technology Transition Processes

Presenter: Michael Sullivan currently serves as Director, Acquisition and Sourcing Management, at the U.S. Government Accountability Office (GAO). This group has responsibility for examining the effectiveness of agency acquisition and procurement practices in meeting their mission performance objectives and requirements. In addition to directing reviews of major weapon system acquisitions, Mr. Sullivan has developed and directs a body of work examining how the Department of Defense (DoD) can apply best commercial practices to the nation's largest and most technically advanced weapon systems. This work has spanned a broad range of issues critical to the successful delivery of systems, including quality assurance, transition to production, technology inclusion, requirement setting, design and manufacturing, reducing total ownership cost, software management, and affordability. His team also provides the Congress with early warning on technical and management challenges facing these investments.

Mr. Sullivan has been with GAO for 20 years. He received a BS in Political Science from Indiana University and an MS in Public Administration from the School of Public and Environmental Affairs, Indiana University.

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What GAO Found

Leading commercial companies use three key techniques for successfully developing and transitioning technologies, with the basic premise being that technologies must be mature before transitioning to the product line side.

- **Strategic planning at the corporate level**: Strategic planning precedes technology development so managers can gauge market needs, identify the most desirable technologies, and prioritize resources.
- **Gated management reviews**: A rigorous process is used to ensure a technology's relevancy and feasibility and enlist product line commitment to use the technologies once the labs are finished maturing them.
- **Corroborating tools**: To secure commitment, technology transition agreements solidify and document specific cost, schedule, and performance metrics labs need to meet for transition to occur. Relationship managers address transition issues within the labs and product line teams and across both communities. Meaningful metrics gauge project progress and process effectiveness.

Not only does DOD lack the breadth and depth of these techniques, the department routinely accepts high levels of technology risk at the start of major weapon acquisition programs. The acquisition community works with technologies before they are ready to be transitioned and takes on responsibility for technology development and product development concurrently, as shown in the following figure. A defined phase for technology transition is not evident. These shortcomings contribute significantly to DOD's poor cost and schedule outcomes.

Why GAO did this Study

The Department of Defense (DOD) relies on its science and technology community to develop innovative technologies for weapon systems, spending $13 billion on basic, applied, and advanced technology research. Several GAO reports have addressed problems in transitioning technologies to the acquisition community. This report, which was prepared under the Comptroller General's authority to conduct evaluations, compares DOD's technology transition processes with commercial best practices. Specifically, GAO identifies technology transition techniques used by leading companies and assesses the extent to which DOD uses the techniques.

What GAO Recommends

GAO recommends that DOD strengthen its technology transition processes by developing a gated process with criteria to support funding decisions; expanding the use of transition agreements, relationship managers, and metrics; and setting aside funding for transition activities. DOD generally agreed with GAO's recommendations with the exception of adopting process-oriented metrics and setting aside funding for transition. It cited ongoing initiatives it believes address several of the recommendations. GAO believes DOD's actions to date are incomplete and all recommendations warrant further attention.

www.gao.gov/cgi-bin/getrpt?GAO-06-883.

To view the full product, including the scope and methodology, click on the link above. For more information, contact Michael J. Sullivan at (202) 512-4841 or sullivanm@gao.gov.

Crossing the Technology Transfer Chasm: Network Externalities, Coordination Games and Lessons Learned from ACTDs

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Abstract

Technology transfer, getting new and improved weapon systems into the hands of our warfighters, has been a persistent problem in the Department of Defense. Advanced Concept Technology Demonstrations (ACTDs), more recently re-designated Joint Concept Technology Demonstrations (JCTDs), have been introduced to help facilitate the technology transfer process. ACTDs programs are designed to demonstrate commercial-off-the-shelf (COTS) technologies that can be modified to serve joint service requirements. COTS technology and joint service requirements are two essential features for ACTDs. Once the technology has been demonstrated, the ACTD is expected to be transferred to a program of record for acquisition and fielding.

Unfortunately, ACTDs have frequently experienced trouble crossing what has been referred to as the “chasm,” the transition from successful technology demonstration and usage by early adopters to acquisition and fielding by a significant share of potential users. In actuality, the transition from technology demonstration to acquisition and fielding for joint service technologies involves coordination across several stakeholders and network externalities (network externalities are present when adoption by one stakeholder affects the benefits of adoption by other stakeholders—a characteristic common in joint service programs).

Analysis of these programs inevitably raises questions about the causes of relative “success” or “failure” of technology transfer, particularly when the programs involve a large number of DoD stakeholders. Much research on the success of acquisition programs

focuses on program management. For example, a recent GAO report criticized the management of the DoD's passive RFID acquisition program (Solis, 2005, September). We think that experimenting with coordination (weak-link) games and/or network externality models in the lab might shed some light on why certain types of coordination problems arise in the first place, how decision-makers can be expected to respond, and what might be done about them.

Research has long explored these issues. The key insight this research brings to the table is that all coordination problems generally exhibit the same underlying properties—i.e., they can be reduced to a single simple and parsimonious "game" called a "weak-link" game that is played by multiple individuals who depend on each other for the overall result or outcome of the game. This weak-link game has already been "played" in experimental economics laboratories, and there is emerging research literature on the properties of this game and the implications of these lab discoveries for real-life situations that are analogous to the weak-link game. In part, this research plans to extend this model to coordination in technology transfer.

At the same time, the theory of network externalities is well developed; but, there is limited experimental data indicating how decision-makers might respond to alternative policy mechanisms. In theory, decision-makers will under-value their decisions to adopt new technology because they will not internalize the value their adoption decisions have on other potential adopters. This might help explain the reluctance of individual services to be early adopters for joint service technologies. Empirically exploring network externalities in experimental settings might help shed light on how to best address this market imperfection in military technology diffusion, particularly as ACTDs face the technology transfer chasm.

This research examines the past transition successes and failures of ACTD programs and uses this experience to develop a model(s) of the coordination issues and/or network externalities involved in the technology transfer process. Once developed, this research proposes to develop economic experiments involving coordination games and network externalities to see if this empirical evidence can emulate the technology transfer chasm.

Development vs. Deployment: How Mature Should a Technology be Before it is Considered for Inclusion in an Acquisition Program?

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Author: Diane Kollar is Director of Industry and Government Relations for the Tennenbaum Institute at the Georgia Institute of Technology. Prior to this position, she was the Director of Development for the School of Industrial and Systems Engineering at Georgia Tech. She has held several positions at Georgia Tech before which she was Associate Director of Development at The Carter Center. She has served in various other development roles in a range of nonprofits, including positions in corporate relations and public relations. Her interests and expertise include resource-development strategy formulation and organizational implementation, particularly in public sector and nonprofit enterprises, as well as public policy issues associated with such strategies and organizations. Ms. Kollar received her BA in Government and International Studies and Master of Public Administration from the University of South Carolina. She also attended the Bryce Harlow Institute on Business and Government Affairs at Georgetown University and studied organizational behavior at Florida Atlantic University.

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Abstract

Modern military systems increasingly rely on the integration of multiple advanced technologies. While these technologies vastly increase warfighter capabilities, they also introduce risk into the system design and development process that tends to increase both its cost and duration. As acquisition cycle-times increase, warfighters must make do with dated technology for longer periods. Thus, there is an incentive to push as many advanced technologies as possible into each program to maximize warfighter capability over the next acquisition cycle. Unfortunately, the more new technologies a system has, the more risky its acquisition becomes, and consequently, its duration and cost increase even further. Thus, there is a feedback effect that exacerbates the problem. Open-architecture designs can partially alleviate this problem, but some technology decisions are so integral to a system's design that they cannot be relegated to future upgrades. Consequently, there is a tradeoff between incorporating these technologies now and increasing program risk or developing and evaluating them further but potentially postponing their application to future acquisition cycles. Our paper will examine this tradeoff by considering a new technology's contribution to program risk.

Introduction

Despite repeated attempts at reforming the defense acquisition process, Defense Department programs continue to experience substantial cost overruns, schedule delays, and performance shortfalls. While there are likely multiple causes for reform failure, this paper aims to address only one of the critical issues that contribute to these acquisition challenges. That issue is the maturity of critical technologies employed in major defense acquisition programs.

There have been repeated calls for the Department of Defense to use evolutionary rather than revolutionary acquisition strategies. In fact, the DoD has revised its acquisition polices to that end (GAO, 2003). Despite these new policies, recent GAO reports have indicated that most major acquisition programs are still revolutionary rather than evolutionary and do not follow current DoD guidelines for knowledge-based acquisition (GAO, 2006, April 5; 2006, April 13; 2006, December 21). It seems that every program is an exception. Why is this?

To that end, this paper investigates two key questions: What level of maturity is acceptable for a technology to be included in a major acquisition program, and what obstacles prevent the DoD from implementing an evolutionary acquisition process?

Our findings will show that, relatively speaking, it is better to employ mature technologies; thus, an evolutionary strategy is superior under most circumstances to a

revolutionary strategy in terms of getting capabilities delivered to the warfighter. We also found, however, that when a program relies on multiple, critical technologies, especially those intended for a multi-mission role, the evolutionary strategy is unstable. There is a natural tendency to revert to the revolutionary technology strategy even though it is not in the best interest of the warfighter.

This paper is structured in the following manner. First, we discuss the background of knowledge-based, evolutionary acquisition and why it is considered important for defense acquisition. Second, we develop a high-level simulation model of acquisition to help us investigate these issues. Third, we use the model to analyze defense acquisition policy alternatives regarding technological maturity. Finally, we conclude with the policy implications of this analysis.

Background

The troubled history of the DoD acquisition system (as well as the repeated attempts to reform it) are well known, and we will not recount them here (See Pennock, Rouse & Kollar, 2007 and GAO, 2006, April 13). Instead, our focus will be on the more recent attempts to reform the acquisition system by employing knowledge-based business practices and evolutionary acquisition.

A common criticism of the defense acquisition process is that it tends to emphasize large leaps in capability achieved by utilizing promising but immature technology. Changes to defense acquisition policy over the last several years have attempted to reverse this trend by creating a milestone process in which programs must meet certain requirements before proceeding from one phase to the next (DOD, 2003a, 2003b). (See Figure 1.) Part of this milestone process is an assessment of the maturity of technologies to be employed in acquisition programs as well as a plan to manage their development.

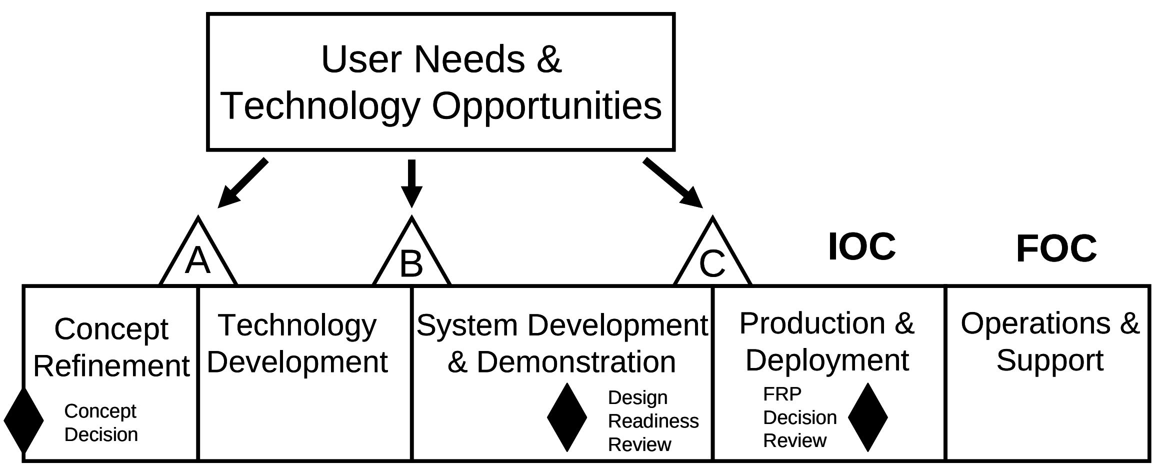

Figure 1. Defense Acquisition Management Framework
(DoD, 2003b)

Technological maturity is typically assessed using the Technology Readiness Level (TRL) scale (Table 1). The TRL scale is a qualitative assessment scale that is designed to aid decision-makers by providing some sense of a given technology's level of risk. In

general, one assumes that the higher the TRL level, the less uncertainty a technology brings to a program. It is important to note that the TRL scale evaluates a technology in isolation and does not consider the integration risks (Smailing & deWeck 2007). Regardless, the aforementioned policy changes encourage programs to utilize more mature, demonstrated technologies (i.e., higher TRL levels) rather than more immature and, consequently, more risky technologies. For example, qualification to enter the system development phase nominally requires all critical technologies to be at TRL level 6 or higher (though the GAO recommends at least TRL level 7 (GAO 2006, April 13)).

Technology Readiness Level	Description
1. Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3. Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard validation in laboratory environment.	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.
5. Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.
6. System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated operational environment.
7. System prototype demonstration in an operational environment.	Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment such as an aircraft, vehicle, or space. Examples include testing the prototype in a test-bed aircraft.
8. Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9. Actual system proven through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under

	operational mission conditions.

Table 1. DoD Technology Readiness Levels
(DoD, 2006, Ch. 10.5.2)

What is the rationale behind a policy that requires a relatively mature level of technology? The issue is that development of immature technology is fairly unpredictable in terms of cost, schedule, and efficacy. When a program contains multiple immature technologies, these tend to delay the program and add cost. If technology development is done in concurrence with system development, the problem can be exacerbated because unforeseen outcomes can lead to significant rework. The net result is that, on average, programs with immature technologies will take longer and cost more. Consequently, warfighters must make due with obsolete equipment longer, thus increasing the chances that they will engage in combat operations with less capability than they could have had otherwise.

As a result, it would seem that a superior approach would be to reduce cycle-time by setting more modest goals for each deployed increment of capability. This is often referred to as an evolutionary rather than a revolutionary acquisition process, and there are several ways to achieve such a process. First, one can make use of open-architecture design and spiral development. The idea behind spiral development is that the system can be deployed with an initial mature technology, which can then be upgraded over time (Johnson & Johnson, 2002). This approach can work well for technologies that are loosely coupled to the system design. In other words, there is a clear, well-defined interface such that changes in the implementation of the subsystem or technology to be upgraded do not interfere with the rest of the system. Open architecture design is perfect for a technology such as a software algorithm. Assuming that the software interface has been standardized, it is comparatively straightforward to replace an old software component with a new one. This approach, in fact, has been demonstrated successfully on submarine acoustic systems (Boudreau, 2006).

When technologies or subsystems are tightly coupled to the overall system, however, any changes to the design of the subsystem impact the design of the whole system. Thus, open-architecture design is not always a feasible alternative. An extreme example would be the hull-form of a surface combatant. Take, for instance, the tumblehome hull design of the new Zumwalt-class destroyer. If some critical issues were to arise with the hull design, it is likely that a significant portion of the ship would have to be redesigned. Of course, hull form is a rather obvious case, but there are many mission-critical systems in any modern military system that exhibit varying degrees of interaction with the rest of the system design. Since changes to these systems would require substantial rework, it is imperative that they be mature prior to system integration, hence the appeal of evolutionary acquisition.

Under evolutionary acquisition, system acquisition cycles are more rapid and make use of mature, available technology. The development of new technologies is detached from the acquisition process, so that the fate of a program does not hinge on the success or failure of any one risky technology. The evolutionary design process is enforced via a knowledge-based acquisition process. The program contains a number of evaluation points or milestones. At each milestone, the program must demonstrate that it has met certain developmental requirements in order to proceed to the next phase. For example, Milestone A entails requirements such as an Initial Capabilities Document, an Analysis of Alternatives (AoA), a Systems Engineering Plan (SEP), and Technology Readiness Assessment.

Despite the fact that the DoD acknowledges evolutionary and knowledge-based acquisition as best practices and has committed them to policy, recent GAO reports have indicated that most major acquisition programs do not follow these polices (GAO, 2006, April 5; 2006, April 13; 2006, December 21). Consequently, these major acquisition programs have continued to experience significant cost overruns and major delays. In particular, these reports have indicated that most major acquisition programs are revolutionary rather than evolutionary, and they are permitted to bypass major milestone requirements. Most rely on multiple immature technologies that are not fully developed before overall system development begins. The Office of the Secretary of Defense (OSD) has acknowledged that this is a common practice (GAO 2006, April 13).

One example in particular that makes the consequences of this acquisition approach clear is the case of WIN-T and JNN-N. The Warfighter Information Network-Tactical (WIN-T) is the next generation tactical communications network for the US Army and will provide a major leap forward in battlefield communications. However, when the program moved into the system-development phase, 9 of the system's 12 critical technologies were immature (GAO 2006, December 21). As a result, WIN-T has been unavailable for both Operation Iraqi Freedom and Operation Enduring Freedom. Because it was determined that there was an urgent need for better battlefield communications to support these two operations, the Joint Network Node-Network (JNN-N) program was created. To address this urgent need, the JNN-N program bypassed many of the normal acquisition procedures to accelerate fielding of the system. While this may be understandable given the urgency of the situation, acquisition procedures are in place to ensure that acquired systems function properly and are cost-effective. As the GAO points out:

> When the Army opted to pursue large technology advances in networking capabilities to support the future forces through WIN-T, rather than pursuing a more incremental approach, it accepted a gap in providing tactical networking capabilities to the warfighter […] If the Army had followed DOD's acquisition policy preferences, which emphasize achieving capabilities in increments based on mature technologies to get capabilities into the hands of the user more quickly, it might have been able to get needed communications capabilities to the warfighter sooner. (GAO 2006, December 21)

Thus, a more evolutionary approach to acquisition may have reduced the risks to the warfighter by both avoiding capability gaps as well as mitigating the need for emergency programs that bypass the usual acquisition procedures.

To summarize, the Department of Defense claims to favor evolutionary acquisition, but does not follow through in practice. The GAO asserts that there are a number of causes for this, one of which is the lack of mandatory controls on the milestone process (GAO 2003, 2006, April 5, 2006, April 13, 2006, December 21). But if evolutionary acquisition is superior, why would the DoD not follow its tenets even without the mandatory controls? There are really two possibilities. Either evolutionary acquisition is not the best approach and when given the flexibility program managers avoid it, or the nature of the acquisition system itself works against the successful implementation of evolutionary methods.

Analysis Approach

To better understand the nature of evolutionary acquisition, we must model the impact of a program's technology strategy on the level of capability actually deployed in the field. In particular, a technology strategy consists of the technologies selected to improve each capability that a system provides. A technology policy that emphasizes major increases in capability would likely rely on immature technology and, thus, would be a revolutionary strategy. Consequently, the acquisition program will require a substantial technology development phase. On the other hand, a technology strategy that emphasizes small improvements in technology would rely on more mature technology and could be considered an evolutionary strategy. This type of strategy effectively detaches technology development from the acquisition program and, consequently, would have a relatively short technology-development phase.

What we would like to examine is the impact of the selected technology strategy over the long-term. Thus, we are concerned with the deployed capability resulting from a sequence of acquisition programs. In particular, we are assuming that our objective is to improve the capabilities of a particular class of system such as a surface combatant or air superiority fighter. To model this, we must establish a means to link the selected technology strategy to the time required to complete an acquisition program. This will determine when a capability improvement is deployed. After an acquisition program completes, we assume that another begins immediately to procure the next iteration of that system.

To accomplish this, we will assume that we can model each acquisition program as a small PERT chart. PERT charts are a common program management tool for managing schedule risk. For our particular model, we will assume a fairly simple formulation. We will assume that there is a technology-development stage followed by a system-integration stage. Each acquisition program contains a number of critical technologies that must be developed for the program to reach a successful conclusion. We will assume that each critical technology can be developed in parallel, but all must be complete before system integration can begin. This is an admitted simplification that works both for and against the acquisition program. The assumption of parallel technology development is somewhat optimistic as the outcome of each critical technology may be somewhat interdependent. The assumption that all development must be completed is somewhat pessimistic because some integration work can be done based on the estimated outcome of technology development. However, since unanticipated outcomes in the technology-development phase can lead to substantial rework in the integration phase, this is not an unreasonable assumption. Given those assumptions, we can structure each acquisition program as shown in Figure 2.

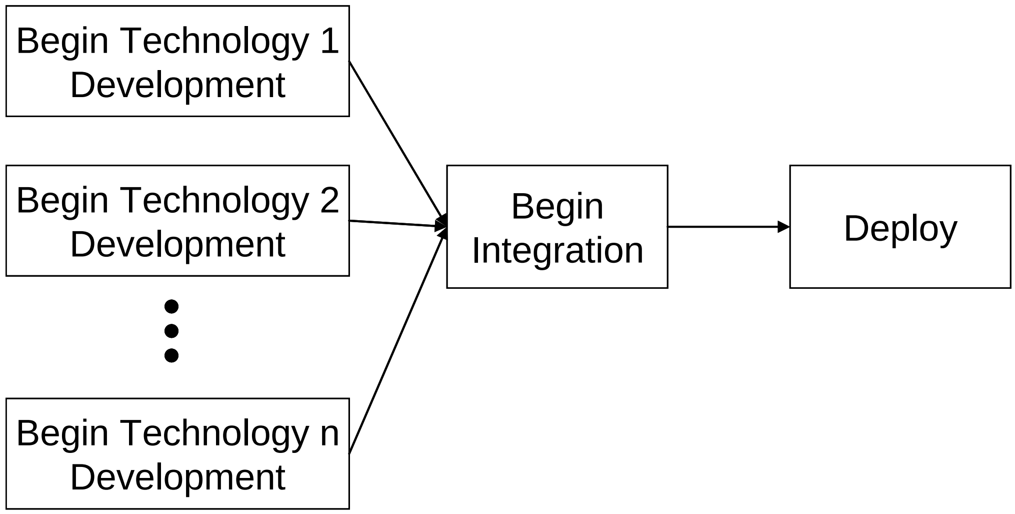

Figure 2. Simplified PERT Chart for an Acquisition Program

Keeping in line with the standard PERT formulation, we will assume that the duration of each technology development activity is stochastic and beta distributed (Figure 3). The beta distribution is appealing is this context because it has finite upper and lower bounds on the activity duration, hence its use in PERT.

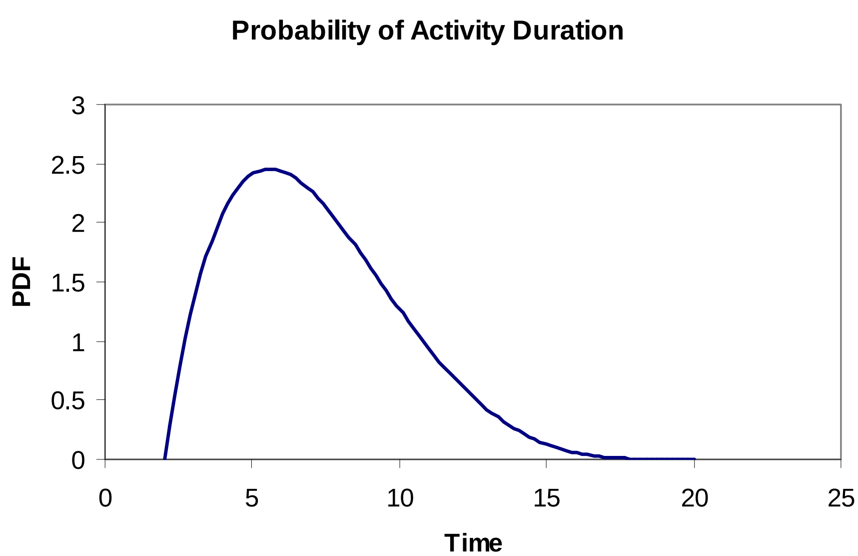

Figure 3. Example Beta Distribution ($\alpha = 2$, $\beta = 5$)

One notion we would like to capture is the relationship between the maturity of a technology selected for an acquisition program and the amount of schedule risk it entails. It is fairly safe to assume that the more immature a technology is, the more schedule risk there is in its development. In fact, we can go one step further and assume that it follows the law of diminishing returns. In other words, each additional increment of schedule risk that we

accept buys a reduced amount of gain in capability. To make this relationship more concrete, we must select metrics for the gain in capability and the level of schedule risk. For the former, we will consider the percent gain in capability over the currently deployed capability. Thus, a relatively low percent gain would be considered an evolutionary technology whereas a large percent gain would be a revolutionary technology. Since we would only accept an immature technology in exchange for an increase in capability, we can assume that for the purposes of our model, the percent gain in capability is also an acceptable proxy for technological maturity. As for the risk, we will assume that schedule risk is encapsulated in the upper bound of the probability distribution for the duration of technology development. For the sake of simplicity, the lower bound and shape parameters of the beta distribution will remain constant. Thus, if we select a particular percent gain in capability as our technology policy, it determines a particular upper bound on the distribution of the development time of that technology. This is illustrated in Figure 4. When we change the upper bound of the distribution, two things occur. We increase the expected time to develop the technology, and we increase the spread of the distribution.

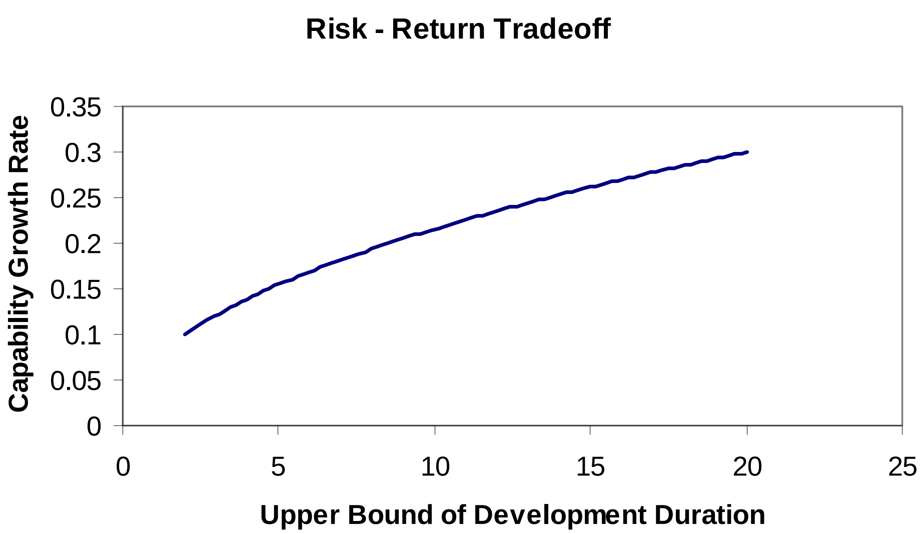

Figure 4. Tradeoff between Risk (the Upper Bound on the Duration of Technology Development) and Return (the Growth in Capability)

We define a technology policy as the targeted percent gain in capability for each acquisition program. Thus, if a more aggressive target is selected, there will be a greater increase in capability for each new system deployed. However, the expected duration of the acquisition cycle will also increase. Given our model structure, we can use Monte Carlo simulation to generate possible capability trajectories. This is accomplished in the following manner. First, sample from the beta distribution for each technology is included in the acquisition program. The integration phase cannot begin until all technology development is complete, so the longest sampled time dictates the length of the technology-development phase. That time plus the time required for integration is the total time required for the acquisition program. At the end of the acquisition program, each capability is increased by the gain targeted in the technology policy. The process then repeats again with the next

acquisition program. This yields a capability trajectory for the technology policy. One example is shown in Figure 5.

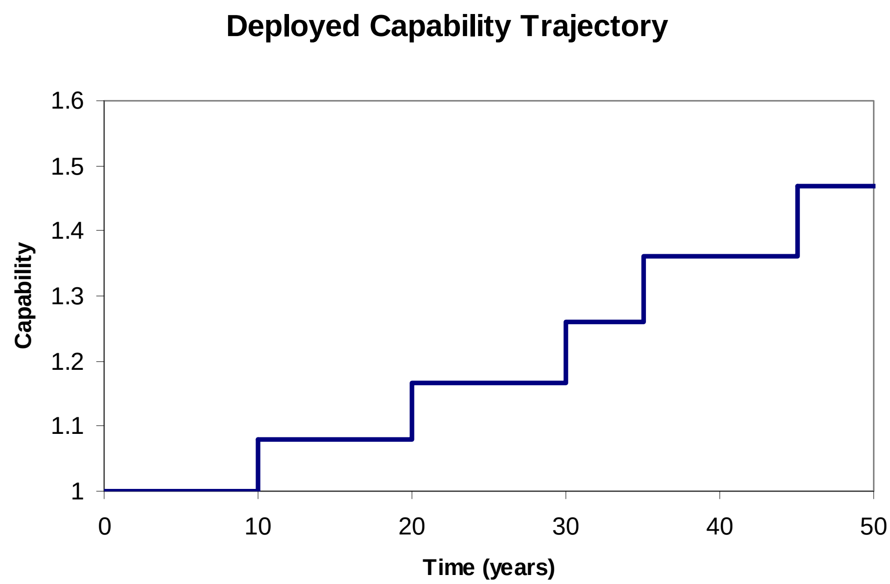

Figure 5. Sample Capability Trajectory

We see in Figure 5 that, with our model, the capability trajectory is a step function because of the discrete nature of acquisition programs. Thus, we see that the longer the acquisition cycle, the longer warfighters must make due with older equipment. To facilitate analysis, we would like to capture the value of any given capability trajectory as a single number. We will do so through the average deployed capability. To calculate the average deployed capability, we select a time horizon, say 50 years, and then calculate the average value of capability over that time interval. While this is not a perfect metric, the notion we are trying to capture is the level of capability that warfighters can expect from their equipment if they are forced to engage in hostilities without warning. This allows us to compare the competing strategies of small-but-rapid capability increments versus large-but-infrequent capability increments. If we generate many sample capability trajectories for a particular technology policy, we can calculate the expected average deployed capability to evaluate the efficacy of that policy.

Analysis Results

The first question we would like to consider is whether it is better to pursue an evolutionary vs. a revolutionary technology strategy. From a purely performance standpoint, we can answer this question using the model we described above but with only a single technology for each acquisition program. To make this more concrete, we will assume some parameter values and run our Monte Carlo simulation over a range of technology policies. In particular, the range we consider is a capability gain per acquisition cycle

between 10 and 30%. The relationship to the upper bound of the duration distribution is described in Figure 4. This is just the function:

Function 1. $\text{Capability Gain} = 0.071841(\text{Upper Bound})^{0.477121}$

Of course, other functional forms are possible, and we will discuss these in more detail later. Under this function, the upper bound of the resulting beta distribution can vary between 2 and 20 years. As far as defining the rest of the beta distribution, the lower bound is always 2 years, and the shape parameters are $\alpha = 2$ and $\beta = 5$. For the purposes of calculating the average deployed capability, the initial level of capability is always one, and the time horizon is 50 years. To emphasize the impact of technology development, we will assume that the duration of the system-integration step is zero. When we run the Monte Carlo simulation for the for possible technology policies within the range of 10 to 30% capability gain, we obtain the results that are depicted in Figure 6.

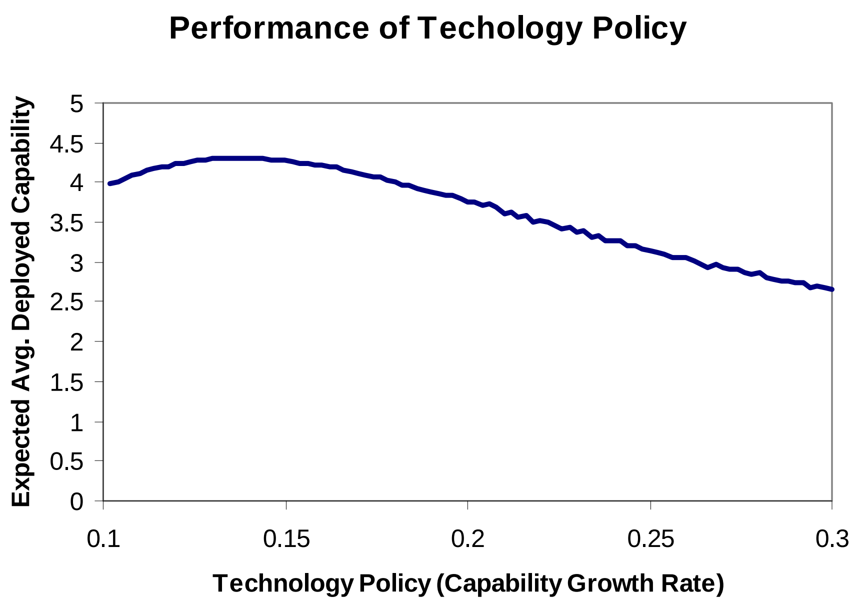

Figure 6. Performance of Technology Policies for a Single Technology

We can see in Figure 6 that there is a single optimal technology policy for our performance metric: expected average deployed capability. In fact, the optimal policy is a relatively modest 13.8% target improvement in capability for each acquisition cycle. This policy results in an expected average deployed capability of 4.31. This result seems to suggest that from a performance standpoint it is better to take smaller, more frequent steps than larger, less frequent steps. In other words, evolutionary is better than revolutionary. But is this always the case? There are two critical features of this model that we can vary. First, we can alter the integration time. In the above case, it was set to zero. But if, for example, it was set to two years, the single technology optimal policy increases to 20%. This result is reasonable because longer integration times essentially impose more overhead on the acquisition process. Consequently, it is advantageous to target a larger

increase in capability to compensate for the integration delay. However, in this model, system integration is not linked to the maturity of the technology selected. In some cases, a more immature technology may be more difficult to integrate with the rest of the system and, hence, would actually exacerbate delays.

Impact of Risk vs. Return

The second feature of the model we should consider is the shape of the curve that relates risk and return. The function used in our model is displayed in Figure 4. This curve exhibits the diminishing return to increasing risk that was mentioned earlier. But what would happen if the penalty for additional risk were more severe? In other words, what if taking on large amounts of risk resulted in very little gain in capability? As an excursion, we will assume that the relationship between the gain in capability and the upper bound of duration is determined by the following exponential relationship.

Function 2. $$\text{Capability Gain} = -0.81104\ e^{-0.7\ \text{Upper Bound}} + 0.300001$$

We find that under this risk-return model, the optimal single technology policy increases to 26%. If, on the other hand, we removed the diminishing returns to risk entirely, we would use the following linear relationship:

Function 3. $$\text{Capability Gain} = 0.011111(\text{Upper Bound}) + 0.077778$$

Under this function our optimal policy is 10%, the minimum allowable. This behavior is perhaps better understood visually. Figure 7 shows all three of the curves discussed. Note that all three pass through the same maximum and minimum points, so the issue is just the shape of the curve. Notice also that the exponential curve increases sharply then flattens out. The high initial derivative means that on the lower end of the curve, one can actually gain quite a bit of capability for very little risk. But the curve quickly flattens out such that each additional gain in capability requires a huge increase in risk. Thus, there is a natural optimal point. The same is true for the baseline curve. While it is not as severe, there is essentially a natural optimal increment size. For the linear curve, the derivative is constant, so the best strategy is to minimize the size of the increment. In this extreme case in which there is no integration time, we can essentially deploy infinitesimally small increments of capability continuously. Thus, the linear case ensures that the best possible capability is available at any time. While this case would be desirable, it is certainly not realistic. Something akin to the baseline case is more reasonable because, in reality, there is usually some minimum reasonable increment that can be deployed.

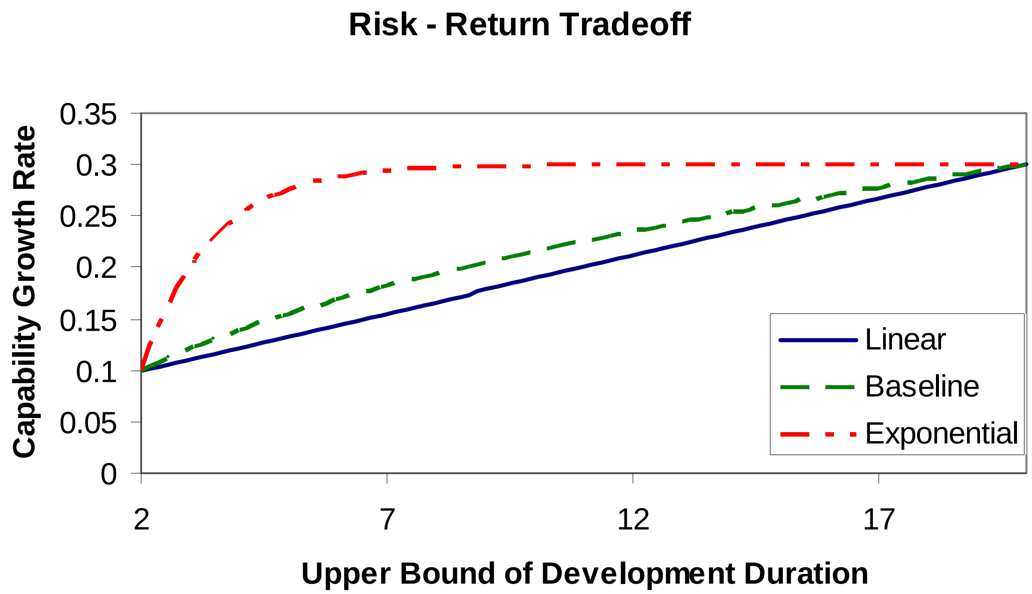

Figure 7. Comparison of Different Risk-return Relationships

It is important to note that changing the scale of the risk-return relationship will certainly change the optimal policy, but here we focused on the shape. This is because the shape of the curve is what determines how aggressive the optimal policy is within the feasible ranges of capability and risk. What we can conclude from this analysis is that, from a performance standpoint, there is a natural optimal technology policy, and, except in extreme circumstances, that policy is not going to be the maximum achievable leap in capability.

Impact of Multiple Technologies

Thus, for a single technology we find that the best policy will most likely be to take small steps with more mature technologies; but what happens when a program depends on the integration of multiple critical technologies? First, we will assume that each technology provides a different capability. For example, a multi-mission surface combatant would have critical technologies that provide anti-air and anti-submarine warfare capabilities. Presumably, stakeholders for each area or capability would want to maximize their respective average deployed capability. But with multiple technologies in the same program, the actions of one affect the outcome for others. For example, the selection of an immature technology for anti-air warfare could delay the delivery of the next ship class and, consequently, delay the deployment of the next generation of anti-submarine warfare technology. From the perspective of stakeholders in anti-submarine warfare, the expected delay means that if they must wait, they should target a larger gain in capability for their area to compensate for the delay. But since program completion depends on both technologies, the reciprocating decision could actually exacerbate delays further. In order to understand stakeholder behavior when a program incorporates multiple critical technologies, we will

employ game theory. (For an introductory treatment of game theory see Gibbons (1992). For a more advanced treatment see Fudenberg and Tirole (1991).)

Game theory allows us to consider the strategies of rational competing parties. A technology policy would be the targeted percent increase for each capability for each acquisition cycle. For example, for anti-air we might target a 15% increase per cycle, while for anti-submarine we might target a 10% increase. Presumably, stakeholders for each area want to maximize the average deployed capability for their area of concern. To employ game theory, we must find the best response functions for the stakeholders for each of the capability areas. We can accomplish this by finding the optimal response to each possible action by the other player. Any intersection points between the best response functions constitute Nash equilibria. A Nash equilibrium is a stable point in strategy at which either player would be worse off if they deviated from that strategy. To demonstrate this concept, we will assume that there are two critical technologies in each acquisition program. Both have the identical risk-return behavior from the baseline case above. The resulting best response functions can be seen in Figure 8.

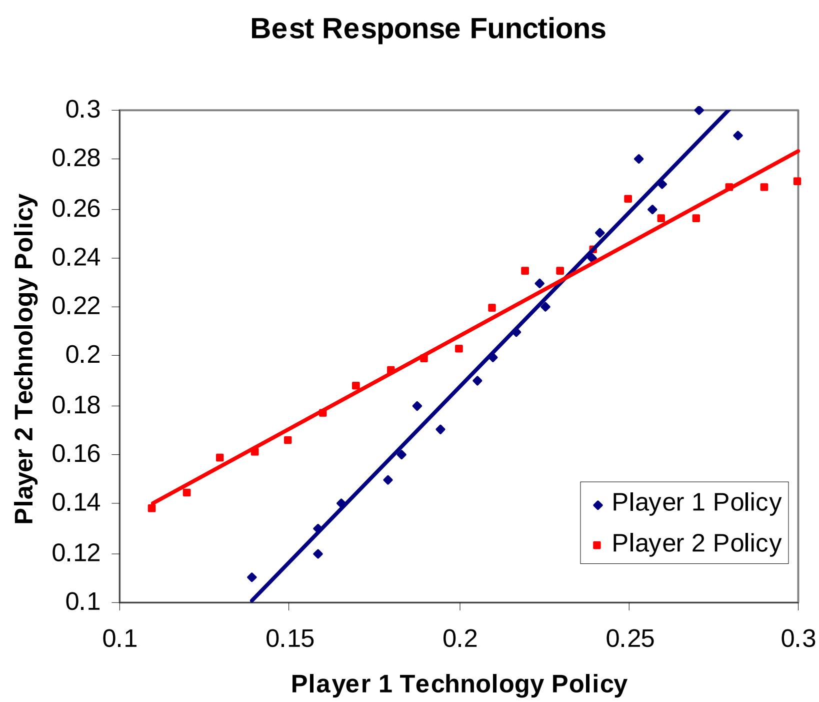

Figure 8. Stakeholder Best Response Functions for a System with Two Critical Technologies

(The intersection of the two functions is the Nash equilibrium.)

The plotted points in Figure 8 represent the best responses over the selected policies. Since Monte Carlo simulation was used, there is some statistical noise in these results. Consequently, a linear function was fit to the best response data for each player. We can see from the best response functions that the two players engage in reciprocating competition. That is, as each player increases his targeted capability, the best response of

the other player is to increase his as well. Since we assumed two identical players, the Nash equilibrium is symmetric and much more aggressive than what is optimal for a system with single critical technology. In fact, the equilibrium solution is for each player to target a 23% increase in capability for each acquisition cycle—resulting in an average deployed capability of 2.7 for each. This is far below the optimal single technology result of 4.31. The practical implication is that older generations of technology stay in the field much longer.

The resulting Nash equilibrium would seem to corroborate the behavior described previously. If one player chooses a particular technology policy, it is in the best interest of the other player to choose one that is just slightly more aggressive. Consequently, the first player might as well choose a more aggressive one himself, and so on. The result is an equilibrium state with a much more aggressive technology policy than we would expect from the single technology analysis. To better understand this result, let us consider the case in which there are still two critical technologies, but the two players cooperate in selecting a technology policy.

To find the best cooperative technology policies, we can search over a grid of possible policy combinations. The results are plotted in Figure 9. The plotted points form the space of all possible policy outcomes. Since we would like to maximize the performance over each capability, we must find the Pareto optimal set of polices. A Pareto optimal policy is defined such that to improve performance of one capability would mean sacrificing performance on another. The Pareto optimal set is designated by the squares in Figure 9.

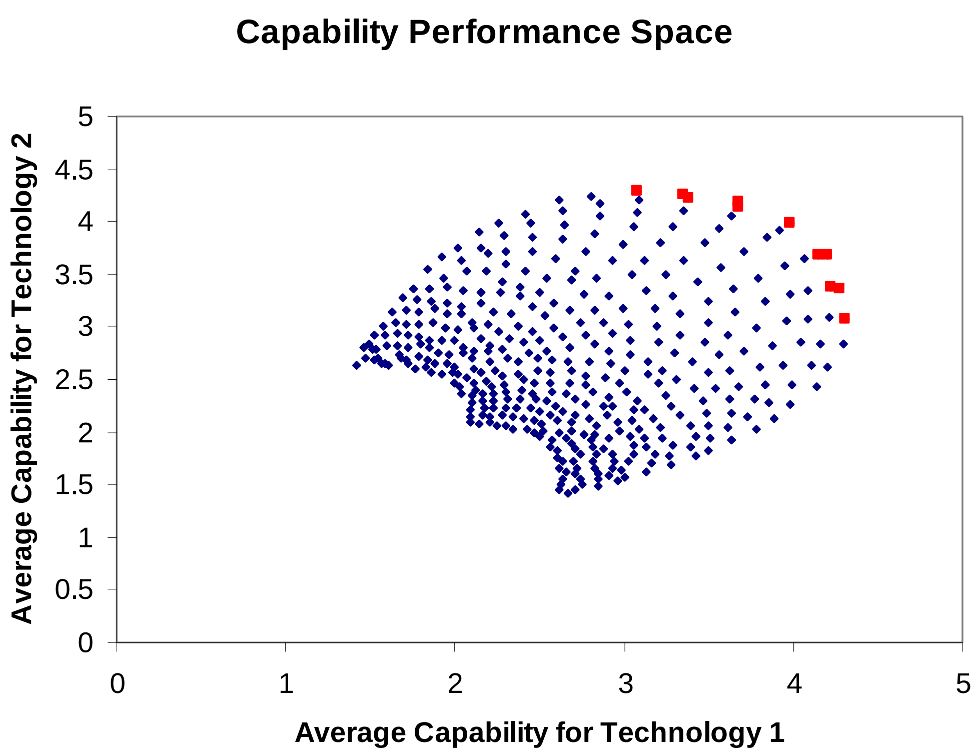

Figure 9. Performance Space of all Possible Technology Policies
(The squares indicate the Pareto optimal set of policies.)

We note that the Pareto optimal frontier allows us to trade off some performance between the two capabilities; but even so, the entire frontier is superior to the Nash equilibrium achieved in the non-cooperative case. For the sake of comparison, let us consider the optimal symmetric policy from the frontier. Under this policy, the target is a 12% improvement per acquisition cycle and an expected average deployed capability of 3.99. Note that this is a significant improvement over the non-cooperative solution but not as good as the single technology solution.

What does this result tell us? We can conclude several things. First, the best solution for a program that relies on multiple critical technologies is a cooperative one in which a small amount of capability is sacrificed from each area to bring the overall cycle-time down. We can see this sacrifice when we compare the optimal symmetric policy to the single technology policy. Thus, we see that there is a price to pay for including multiple capabilities in a single system. While there are likely cost advantages, there will be some sacrifice in performance (barring synergistic effects) because the integration of multiple technologies increases acquisition cycle-time. More importantly, however, is that the optimal solution is not stable in that it is not a Nash equilibrium. Therefore, there is always an incentive to deviate. Let us say, for example, that we select the optimal symmetric technology policy for our system. Assuming that everyone else follows this policy, it is in the best interest of anyone supporting a particular capability to push for a slightly more aggressive technology for his area. He will end up better off. But since all have an incentive to deviate, if one deviates, all will likely deviate, and we end up at the Nash equilibrium. This is exactly where we do not want to be.

To better elaborate on this point, it is instructive to consider the cartel problem from economics. In a cartel, several firms make a price-fixing agreement so that they can all earn greater profits than if they competed. Thus, they set a price higher than the market equilibrium price. However, there is an incentive to deviate. If one firm in the cartel charges slightly less than the agreed-upon price, it will capture the market and make much more money than it would by following the cartel agreement. Consequently, cartels tend to be unstable without strict monitoring and enforcement.

We see that our situation here is quite analogous. For a given system, it is in the best interest of all stakeholders and decision-makers to sacrifice a little bit of capability in each critical area in order to pursue an evolutionary rather than a revolutionary policy. However, it is always in the best interest for any given stakeholder to push for just a little bit more capability in his respective area. Thus, the best solution is unstable. This phenomenon could explain, at least in part, why the acquisition system in the Department of Defense consistently pursues revolutionary rather than evolutionary acquisition programs despite policies to the contrary. The above game theory analysis indicates that in the absence of enforcement, the rational actions of decision-makers with good intentions will lead to poor acquisition policy. The implication here is that if the Department of Defense is serious about evolutionary acquisition, it cannot expect voluntary compliance. Compliance must be enforced.

In the interests of robustness, we should consider the sensitivity of this result. If we increase the integration time to two years, the competitive policy is a 29% increase in capability per cycle for an average deployed capability of 1.78—whereas the optimal symmetric cooperative policy is an 18% increase in capability per cycle with an average deployed capability of 2.05. Thus, an increase in the integration delay makes both policies more aggressive, but the relationship between competition and cooperation is preserved.

As for the shape of the risk-return curve, if we examine the exponential case, we find that the competitive-cooperative relationship is still preserved but becomes less dramatic. The competitive policy is a 27% increase in capability per cycle resulting in an average deployed capability of 11.7—whereas the optimal symmetric cooperative policy is a 24% increase in capability per cycle with an average deployed capability of 12.74. (Note that these average deployed capabilities are very high because the exponential curve allows for large increases in capability very quickly.) Finally, what happens as we increase the number of critical technologies? It turns out that the situation gets worse. If there are three critical technologies, the competitive policy is to pursue a 33% increase in capability per cycle for an average deployed capability of 1.76. Meanwhile, the optimal symmetric cooperative policy for three identical technologies is to target a less-than-11% gain in capability per cycle resulting in an average deployed capability of 3.93.

Thus, the key result from this analysis is that when an acquisition program relies on more than one critical technology, the relationship between competitive and cooperative behavior is fairly robust. The cooperative policy yields superior performance through smaller capability increments but is unstable. Without enforcement, the situation devolves to a suboptimal Nash equilibrium that achieves inferior performance through larger capability increments.

Cost Considerations

Up until this point we have only considered performance, and we have omitted any discussion of cost. An evolutionary approach to acquisition may achieve a higher deployed performance on average, but is it more cost-effective? This question is a little more difficult to answer; it depends in large part on the relative costs to produce and deploy the replacement system (or upgrade the old system) at the end of each cycle, as well as on the relationship between technology maturity and development cost. All else being equal, we can say that there is a tradeoff between cost and performance in terms of cycle-time. More frequent, shorter cycles mean that overhead costs associated with an acquisition cycle are incurred more often. Consequently, costs will increase when the cycle-time is shorter. The relative magnitudes of cycle costs versus development costs will dictate the severity this tradeoff. More expensive development costs reduce the contribution of cycle costs as a percentage of the overall acquisition bill. Thus, the tradeoff becomes less severe. If, on the other hand, cycle costs are very high (e.g., from high manufacturing costs), increasing the length of acquisition cycles may be more appealing.

The missing piece here is the impact of technological maturity on cost. Does the inclusion of immature technology in an acquisition program require the use of more expensive development methods than if the same technology were pursued in a research and development setting? Does the inclusion of immature technology make system integration more difficult and expensive than when mature technology is employed? Conventional wisdom would suggest that the answer to both of these questions is yes, and if so, there could be an optimal technology policy that minimizes cost.

We can demonstrate, at least in a simplistic way, that it is possible to achieve lower costs through an evolutionary strategy. Let us assume that we have a system with a single capability, and we can upgrade that capability though either one large leap or multiple small steps. Both achieve the same end capability, but increasing the number of cycles to achieve it increases the maturity of the technology we use in each cycle. For example, we could achieve a 25% increase in capability all at once or through two steps that sequentially

increase capability by 11.8% each time. The capability outcome is the same in either case, but the time to achieve it may differ. In fact, if we use the baseline risk-return relationship described earlier, the one-step strategy is expected to take 5.27 years (assuming no integration time), whereas the two-step strategy is expected to take 4.46 years. Of course, the addition of integration time could erode the time advantage provided by multiple steps, but at least notionally we can see that there could be some cost advantage to taking multiple, less-risky steps. If we assume that the development costs are the same in both cases, the cost difference comes down to the overhead associated with each acquisition cycle. Again, for the sake of simplicity, if we assume that the cycle costs are the same regardless of the aggressiveness of the technology policy, we can determine the conditions under which the evolutionary strategy is more cost-effective. To make this explicit, let us define some variables.

n = the number of steps in the evolutionary policy

$D(n)$ = the expected length of each step when there are n steps

C_D = the cost rate for development work

C_O = the overhead cost for each acquisition cycle

As above, we assume that we have two policy options that achieve the same increase in capability. However, the first policy option achieves it in one step, while the second achieves it in n steps. We want to find the conditions under which the n-step policy is more cost-effective than the one-step policy.

Equation 1. $$nD(n)C_D + nC_O < D(1)C_D + C_O$$

Rearranging terms yields:

Equation 2. $$\frac{C_O}{C_D} < \frac{(D(1) - nD(n))}{n-1}$$

Thus, we can characterize the cost-effectiveness of the evolutionary policy in terms of the ratio of the cycle costs to the development costs. For the example discussed above, the two-stage policy is more cost-effective when the ratio of the cycle cost to the development cost rate is less than 0.81. However, this analysis is admittedly oversimplified and only reveals the possibility that an evolutionary strategy could be less expensive.

Additional work is needed to model cost in a more realistic manner. Empirical studies regarding software development reveal that for large projects, the cost savings from a spiral approach can be substantial (Boehm, 2007). This occurs because the upfront investment in better systems engineering and spiral risk reduction is outweighed by the reduction in rework. This is especially true for complex software systems. This result, while particular to software systems, is suggestive and may imply that the adverse cost impacts of including immature technologies in a single acquisition cycle may be substantial. Thus, to effectively model cost, we must consider the possible approaches to developing technologies.

One approach is to leave technologies in the R&D process longer so that they are more mature when they are finally included in an acquisition program. The advantage to this approach is that technologies can be managed in a portfolio setting. That means funding can be balanced and allocated to maximize the technological options available to acquisition programs. If, for example, in the course of development, a particular technology proves to be problematic or not as effective as anticipated, funding may be shifted to an alternate approach to provide a needed capability. In contrast, once technologies are included in an acquisition program, some of this flexibility is lost. There is a great deal of commitment to a particular design approach, and it may be difficult or prohibitively expensive to change it in the event that a selected technology underperforms. Thus, to really model the cost implications of evolutionary acquisition, one would need to model the cost impacts of withdrawing technologies from the R&D portfolios at various levels of maturity. This must be relegated to future work.

Conclusions

What we can conclude from this analysis is that, from a performance standpoint, every acquisition program has some optimal technology policy that is dependent upon the nature of the system and technologies involved. Unfortunately, the implementation of this optimal acquisition strategy is not trivial. The increased emphasis on multi-mission or multi-capability platforms may lead to overall cost savings and increased flexibility, but it creates a tension between the competing missions and capabilities. A multi-mission platform means that some capability must be sacrificed relative to a specialized system in order to deliver the system in a reasonable time frame and to maintain the optimal acquisition strategy. The result is that the optimal strategy requires an unstable technology policy that incentivizes stakeholders to deviate from that policy. Thus, there is a tendency in the Department of Defense to pursue an overly aggressive technology policy. In as much as the optimal policy tends to be more moderate than the stable policy, we can say that the former is more evolutionary, while the latter is more revolutionary. The implication is that while evolutionary acquisition is more appealing from a performance standpoint, revolutionary acquisition is the more natural outcome. This means that the Department of Defense cannot expect programs to voluntarily comply with evolutionary acquisition procedures since the nature of the system pressures programs towards revolutionary leaps in technology. Consequently, if the DoD is serious about evolutionary acquisition, technology-maturity requirements must be strictly enforced.

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Panel 3 – The Evolving Defense Industrial Base

Wednesday, May 16, 2007	Panel 3 – The Evolving Defense Industrial Base
11:15 a.m. – 12:45 p.m.	**Chair:** **Lenn Vincent, RADM**, USN (ret.), Industry Chair, Defense Acquisition University, former Commander, Defense Contract Management Command and Commandant of Defense Systems Management College **Discussant:** **Stan Z. Soloway**, President, Professional Services Council and former Deputy Under Secretary of Defense (Acquisition Reform) **Papers:** ***An Empirical Analysis of the Patterns in Defense Industry Consolidation and their Subsequent Impact*** **Nayantara Hensel**, Naval Postgraduate School ***Strategic Sourcing—Is There a Role for Midsize Companies in the Industrial Base Supporting the Federal Government Market Space*** **David A. Drabkin**, US General Services Administration

Chair: Lenn Vincent, RADM, USN (ret.), is a retired U.S. Navy rear admiral with more than 30 years of broad-based and in-depth leadership and management experience in acquisition, supply chain management, logistics and financial management. He is currently the industry chair at the Defense Acquisition University (DAU).

A former vice president at CACI International and American Management Systems, Mr. Vincent was responsible for working with senior Department of Defense and industry leaders to build long-term business relationships and to help identify solutions to acquisition management challenges.

His military assignments include: commandant, Defense Systems Management College; deputy chief of staff for logistics, Fleet Supply and Ordnance, U.S. Pacific Fleet; commander of the Defense Contracts Management Agency; assistant commander for contracts, Naval Air Systems Command; and numerous other contracting officer and contract management positions.

He holds a Masters in Business Administration from George Washington University. He also is a Certified Navy Material and Acquisition Professional, and is DAWIA Level III certified in both Contracting and Logistics.

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An Empirical Analysis of the Patterns in Defense Industry Consolidation and their Subsequent Impact

Presenter: Nayantara Hensel[1] is an Assistant Professor of Economics and Finance at the Graduate School of Business and Public Policy at the US Naval Postgraduate School. She received her BA (magna cum laude) from Harvard University where she was a member of Phi Beta Kappa. She also received her MA and PhD in Business Economics (Applied Economics) from Harvard University. Prior to joining the faculty at the US Naval Postgraduate School, Dr. Hensel served as a Senior Manager at Ernst & Young, LLP and as the chief economist for one of its units, was a Post-doctoral Research Fellow at the National Bureau of Economic Research, taught at Harvard University and the Stern School of Business at NYU, and was an economist at NERA (part of Marsh & McLennan). Dr. Hensel's recent research has examined the impact of size and market structure on efficiency (economies of scale) in European and Japanese banks and on their tendency to open branches or merge, the impact of contracting arrangements and mergers on the utilization of railroad networks, the role of venture capital in the DoD, the determinants of discount rates for military personnel, and the impact of online auctions on IPO pricing efficiency. She has published in a variety of journals, including the *Review of Financial Economics*, the *International Journal of Managerial Finance*, the *European Financial Management Journal*, the *Journal of Financial Transformation*, *Business Economics*, and *Harvard Business School Working Knowledge*.

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Abstract

The defense industry has witnessed significant consolidation since the end of the Cold War. This paper explores the causes of the wave of defense mergers, as well as their impact. The analysis finds that the frequency of defense mergers is more strongly correlated with overall merger activity in the economy than with DoD outlays. In examining SAR cost data on weapons systems, only 50-65% of the weapons systems' costs were affected following consolidation activity by the primary contractor that made them, of which 40% of the systems experienced a statistically significant decrease in their costs, and 15-20% experienced a statistically significant increase. Despite a 2/3 reduction in the number of prime contractors in the fixed-wing aircraft sector between 1990 and 1998, about 60% of the systems experienced a statistically significantly lower cost estimate. For the tactical missile

[1] The author gratefully acknowledges the assistance of Maj. Russell Hoff (US Army) and Capt. Grisko Alfonso (USAF) in categorizing the weapons systems and analyzing the SAR data, as well as the hard work of Lt. David Mazur (USAF) in collecting the SAR data and Christina Fishback in providing information on the dates of the defense mergers. The author appreciates the financial support of the US Naval Postgraduate School Acquisitions Research Program. The views in this article represent only those of the author and not any institution with which the author is affiliated. Please do not quote or cite without permission of the author. See contact information above.

category, in which the number of prime contractors also fell by 2/3, 28.6% of the systems indicated statistically significantly higher post-merger estimates and 28.6% of them indicated statistically significantly lower post-merger estimates. Boeing, Lockheed, and Raytheon were among the few main primary contractors in several sectors following the consolidation wave. About 70-80% of the weapons systems examined in this analysis which were produced by them indicated a statistically significant change in their cost estimates. For Boeing and Lockheed, 50-57% of the systems exhibited a statistically significant reduction in cost estimates, while, for Raytheon, 60% of the systems experienced a significant cost increase. About 2/3 of the systems made by Lockheed and Martin Marietta manifested significant cost declines following the Lockheed-Martin Marietta merger,, and about ½ of the systems made by Boeing and McDonnell Douglas experienced a statistically significant decline in cost estimates following their merger. This suggests that, although market concentration levels may have increased in certain sectors, DoD's costs often tended to be lower in the post-merger period for certain weapons systems.

Introduction

The defense industry has witnessed significant consolidation since the end of the Cold War. As the number of large defense contractors has declined, key public policy questions have arisen concerning whether the mergers have led to greater efficiencies, lower costs, and improvements in quality, or whether they have led to higher costs, fewer choices, and larger firms with unwieldy organizational structures. The purpose of this paper is to examine: (a) the roles of defense spending and broader merger activity in the economy on the frequency and size of defense mergers, (b) the patterns of defense consolidation and some of the related antitrust concerns, and (c) the impact of mergers of major defense contractors on the costs of weapons systems facing DoD.

The Impact of Defense Spending and Broader Merger Activity on Defense Mergers

The wave of defense mergers, particularly during the 1990's, was partially driven by the need to eliminate excess capacity in the industry following the end of the Cold War. Overall defense spending, as well as defense procurement spending, grew rapidly during the 1980's, declined following the end of the Cold War, increased towards the end of the 1990's, and exhibited significant growth with the War on Terrorism. Indeed, overall defense spending grew 73.5%, and defense procurement spending grew 133.1% between 1981 and 1991, while between 1992 and 1996, overall defense spending fell 10.9% and defense procurement spending fell 34.7%. Between 1997 and 2001, overall defense spending and defense procurement spending grew 12.7% and 15.3%, respectively, while between 2002 and 2006, overall defense spending and defense procurement spending grew at 49.7% and 43.6%, respectively.[2] In constant FY 2001 dollars, overall defense spending declined 34.8% between FY 1985 and FY 1996 and declined 25.6% between FY 1990 and FY 1996.

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[2] These growth rates were calculated by the author from the raw data in the Historical Tables (Table 3.2) for the *United States Budget for Fiscal Year 2008*, p. 56-60. The growth rates are not annualized nor adjusted for inflation.

Defense procurement spending declined 67.2% between FY 1985 and FY 1996 and declined 53.77% between FY 1990 and FY 1996.[3]

The wave of mergers in the defense sector was also partially linked to overall merger patterns within the US economy. Table 1 shows the growth rate from year to year in terms of the number of defense mergers and the value of defense mergers, as compared to the comparable growth rates for merger activity in the US economy.

Table 1. Annual Growth Rates in Merger Activity in the Defense Sector and in the Overall Economy

Time Period	Annual growth rates for merger activity (number of transactions) in the defense sector	Annual growth rates for merger activity (number of transactions) in the overall economy	Annual growth rates for merger activity ($ value) in the defense sector	Annual growth rates for merger activity ($ value) in the overall economy
1992-1993	-44.83%	4.008%	-82.37%	45.41%
1993-1994	-6.25%	12.66%	268.1%	80.63%
1994-1995	-33.00%	17.37%	-94.13%	30.94%
1995-1996	100.0%	66.51%	8571.4%	110.8%
1996-1997	50.00%	33.32%	-46.96%	35.68%
1997-1998	70.00%	0.154%	-59.25%	83.41%
1998-1999	0.00%	18.94%	169.0%	19.16%
1999-2000	-29.4%	3.28%	392.8%	832.9%
2000-2001	-5.5%	-13.37%	-97.03%	-94.72%
2001-2002	26.47%	-12.06%	164.7%	-37.42%
2002-2003	-34.88%	9.573%	-55.97%	15.14%
2003-2004	-10.7%	22.66%	50.50%	48.78%

(NOTE: These annual growth rates were calculated by the author from raw data found in *the Mergerstat Review for 2005, the Mergerstat Review for 2002, the Mergerstat Review for 1997*, and the *Mergerstat Review for 1996*. The defense sector, as defined by Factset Mergerstat, encompassed firms in Standard Industry Classification (SIC) codes 3761-3769, 3721-3728, and 3795.)

Growth in merger activity in the defense sector, whether measured by growth in value or growth in number of transactions, was generally lower than growth in merger activity in the overall economy. Growth in merger activity in the defense sector exceeded growth in merger activity in the industry overall (or exhibited less negative growth) in terms of the number of transactions and in terms of value in 5 out of the 12 years (41.67%).

Table 2 shows the number of defense mergers which were over $100 million in value as a percentage of total defense mergers, as well as the percentage of larger mergers of over $100 million in size in the economy as a percentage of total mergers in the economy. The years in which large defense mergers were over a quarter of the mergers in that sector

[3] These growth rates were calculated by the author from the raw data in the *Annual Report to the President and Congress by the Secretary of Defense in 2000*, Appendix B-1. The growth rates are calculated from data in constant dollar terms, although they are not annualized.

were 1992, 1994, 1996, and 2004. In the overall economy, large mergers tended to be a smaller percentage of the total number of mergers due to the total volume of mergers during the mid to late 1990's. Nevertheless, the fifth column suggests that the period of the most mega-mergers in the economy overall stretched from 1994-2000.

Table 2. Percentage of Defense Mergers and Mergers in the Overall Economy Exceeding $100 Million in Value

Time Period	Number of $100m plus transactions as a percentage of total transactions in the defense industry	Number of $100m plus transactions as a percentage of total transactions in the overall economy
1991	0.00%	8.01%
1992	27.59%	7.54%
1993	18.75%	9.03%
1994	40.0%	12.64%
1995	0.00%	13.2%
1996	40.0%	10.84%
1997	20.0%	11.16%
1998	19.6%	11.55%
1999	13.73%	11.81%
2000	16.67%	12.00%
2001	17.64%	8.44%
2002	6.977%	8.33%
2003	10.71%	8.19%
2004	24.00%	8.60%

(NOTE: These percentages were calculated by the author from raw data found in the *Mergerstat Review for 2005, the Mergerstat Review for 2002, the Mergerstat Review for 1997*, and the *Mergerstat Review for 1996*. The defense sector, as defined by Factset Mergerstat, encompassed firms in Standard Industry Classification (SIC) codes 3761-3769, 3721-3728, and 3795.)

Industry observers often cite defense spending and overall merger activity as the two forces behind defense sector mergers (Korb, 1996). But, is defense merger activity more linked to the level of DoD spending or to the overall level of merger activity in the economy? Which one of these is a more significant force? Table 3, which shows correlations between various measures of defense merger activity and merger activity in the overall economy, as well as between defense merger activity and DoD spending, suggests that merger activity is much more strongly linked to overall activity in the economy. This supports the hypothesis that merger activity was not necessarily entirely driven by the need to downsize and reduce excess capacity in the wake of the Cold War.

The correlations use data covering the period between 1992 and 2004. Column 2 shows the correlations between the number of defense mergers in a given year and: (a) the overall level of DoD outlays in that year, (b) the level of DoD procurement outlays in that year; (c) the overall level of DoD outlays in the previous year, (d) the level of DoD procurement outlays in the previous year, and (e) the level of overall merger activity in the economy. Column 3 shows the comparable correlations for defense merger activity as measured by dollar value, rather than by number of transactions.

Table 3. Correlations between DoD Outlays, Merger Activity in the Economy, and Merger Activity in the Defense Sector

Correlation between:	Number of defense merger transactions in a given year	Dollar value of defense merger transactions in a given year
Level of overall DoD outlays in a given year	-0.0269	-0.2058
Level of DoD procurement outlays in a given year	-0.3591	-0.3783
Level of overall DoD outlays in the previous year	-0.1929	-0.2947
Level of DoD procurement outlays in the previous year	-0.6097	-0.3916
Number of mergers in the overall economy in a given year	0.6498	
Dollar value of mergers in the overall economy in a given year		0.9399

(NOTE: The statistical correlations were calculated by the author from raw data found in the Historical Tables (Table 3.2) for the *Budget for Fiscal Year 2008*, p. 56-50, and from the raw data found in the *Mergerstat Review for 2005, the Mergerstat Review for 2002, the Mergerstat Review for 1997*, and the *Mergerstat Review for 1996*.)

The correlations between defense merger activity (regardless of how it is measured) and DoD outlays (regardless of whether it is overall levels or procurement levels, and whether it occurred in the current year or the previous year) are negative, as would be expected—as defense spending goes down, defense merger activity goes up. Nevertheless, the correlations tend to be weak. Procurement outlays move much more strongly in the opposite direction from defense transactions than overall DoD outlays do. Correlating previous year DoD overall outlays and procurement outlays with current year merger activity (in terms of either transactions or value) yields a stronger relationship than correlating current year outlays with current year merger activity. This suggests that, since the merger process requires time, mergers are a delayed response to spending levels in previous years. The tightest negative relationship is between merger activity (as measured by the number of transactions) and DoD procurement outlays in the previous year.

The correlations are strongly positive between merger activity in the defense sector and merger activity in the overall economy in a given year (excluding defense mergers)—as one increases, the other increases. The correlation is strongly positive between the number of defense mergers and the number of mergers in the economy overall (excluding defense mergers) at 0.6498, while the correlation is very strongly positive between the dollar value of mergers in the overall economy (excluding defense mergers) and the dollar value of defense mergers at 0.9399.

In summary, Table 3 suggests that although the wave of defense mergers was driven by both DoD spending and by overall economic merger activity, overall economic merger activity was much more strongly correlated. Consequently, the decline in Cold War spending and its impact on excess capacity was less important than overall economic

growth, stock market conditions, and the need for defense firms to defensively merge as their rivals merged so that they would not be left out in the cold as a relatively smaller firm facing larger, consolidated competitors.

Patterns of Defense Consolidation and Antitrust Concerns

In July, 1993, Deputy Defense Secretary William Perry, at a summit known as the "Last Supper," met with representatives of the major defense contractors and encouraged significant defense sector consolidation (Ricks & Cole, 1998; Cole, 1996). Between 1990 and 1998, the number of prime contractors decreased significantly due to consolidation in 10 of the 12 key defense sectors identified by DoD. These 10 sectors included: tactical missiles, fixed-wing aircraft, expendable launch vehicles, satellites, surface ships, tactical wheeled vehicles, tracked combat vehicles, strategic missiles, torpedoes, and rotary-wing aircraft. Table 4 shows, for each of the 10 sectors, the number of prime contractors in 1990, the number of prime contractors in 1998, and the amount of the percentage decline.[4]

Table 4. Reduction in Prime Contractors in Various Weapons Systems Sectors between 1990 and 1998

Sector	Number of prime contractors in 1990	Number of prime contractors in 1998	Percentage reduction
Tactical Missiles	13	4	-69.2%
Fixed-wing Aircraft	8	3	-62.5%
Expendable Launch Vehicles	6	2	-66.7%
Satellites	8	5	-37.5%
Surface Ships	8	5	-37.5%
Tactical Wheeled Vehicles	6	4	-33.3%
Tracked Combat Vehicles	3	2	-33.0%
Strategic Missiles	3	2	-33.0%
Torpedoes	3	2	-33.0%
Rotary-wing Aircraft	4	3	-25.0%

The percentage reduction in contractors exceeded 60% in 3 of the 10 sectors, and varied between 25% and 37.5% in the remaining 7 of the 10 sectors. The major giants which emerged out of this consolidation across these sectors were Boeing, Lockheed Martin, and Northrop Grumman, and, to a lesser degree, Raytheon and General Dynamics. Between 1990 and 1998, the three sectors which experienced the most consolidation, and which were dominated by contractors which only included Boeing, Lockheed Martin, Northrop

[4] Data on the sectors and the number of contractors in 1990 and 1998 are derived from the *General Accounting Office (GAO) Report to Congressional Committees on the Defense Industry: Consolidation and Options for Preserving Competition*, Washington DC, April 1998.

Grumman, and Raytheon, were: tactical missiles, fixed-wing aircraft, and expendable launch vehicles.

By 1998, Boeing was one of the prime contractors in 6 of the 10 markets: tactical missiles, fixed-wing aircraft, expendable launch vehicles, satellites, strategic missiles, and rotary-wing aircraft. Lockheed Martin was one of the prime contractors in 5 of the 10 sectors: tactical missiles, fixed-wing aircraft, expendable launch vehicles, satellites, and strategic missiles. Northrop Grumman was one of the prime contractors in 3 of the 10 sectors: tactical missiles, fixed-wing aircraft, and torpedoes. General Dynamics was one of the prime contractors in 2 of the 10 markets: tracked combat vehicles and surface ships. Finally, Raytheon was one of the prime contractors in 2 of the 10 markets: tactical missiles and torpedoes.

With the increasing numbers of defense mergers in the mid to late 1990's, the Antitrust Division of the Department of Justice (DOJ) and the Federal Trade Commission (FTC) became more concerned that consolidation was leading to a reduction in competition and an increase in anticompetitive activity. As Joel Klein, Assistant Attorney General of the Antitrust Division of the DOJ noted in his address before the Senate Judiciary Committee in June, 1998, "A number of defense mergers proceeded unchallenged over the last 5 years, which rationalized capacity, but if that rationalization goes too far, it can harm competition" (Klein, 1998). Indeed, the DOJ had challenged two mergers in 1997— Raytheon's acquisition of Hughes Aircraft (the aircraft subsidiary of General Motors) and Raytheon's acquisition of the defense electronics division of Texas Instruments—but then allowed both of them to go through provided that divestitures of certain key divisions occurred prior to the merger in order to protect competition. In 1998, however, the DOJ blocked the merger between Lockheed Martin and Northrop Grumman, since the DOJ believed that the merger would lead to a reduction in competition and innovation in submarine sonar systems, military aircraft radar, and various electronic warfare systems. This proposed $11.6 billion acquisition was the largest acquisition that the DOJ had challenged in its history up to that point (Klein, 1998), and the challenge was supported by the Pentagon since Defense Secretary Cohen also thought that the merger would be anticompetitive (Ricks & Cole, 1998). Lockheed and Northrop called off the merger in July, 1998, prior to their September trial date (Fidler & Lewis, 1998).

Analyzing the anticompetitive impact of consolidation in the defense sector involves different considerations from analyzing consolidation in other industries for several reasons. First, in determining the relevant geographic market of possible competitors, the analysis can't always include foreign weapons manufacturers for security reasons, although, in other industries, foreign manufacturers can be included in defining the boundaries of the market that would be affected by the merger. Second, traditional industries have a broader spectrum of consumers for the product, whereas DoD is the main buyer for weapons systems. Consequently, it plays a highly significant role in the DOJ and FTC deliberations. Third, lower barriers to entry would allow new entrants to enter the market and reduce the possible anticompetitive effects of increased consolidation, such as higher pricing. Nevertheless, the government contracting process makes it harder for new entrants to gain a foothold and tends to give an advantage to incumbent firms, which know the government contracting system better.

Either vertical or horizontal consolidations could contribute to a negative outcome. Vertical mergers might lead to foreclosure to competitors of key input suppliers or distributors along the vertical supply chain. For example, one of the concerns about the

proposed Lockheed Martin-Northrop Grumman merger had been that Lockheed Martin would have control of a key supplier of electronics which supplied Boeing's planes, as well as its own planes. This could enable it to limit Boeing's access to the supplier. On the other hand, Lockheed argued that the Pentagon could monitor the selections of equipment from outside suppliers and that the process was sufficiently transparent that this would not be an issue. Indeed, Lockheed argued that the mission computers in its F-16 planes came from Raytheon (Ricks & Cole,1998). A second example of concerns over vertical integration was when the CEO of McDonnell Douglas, in April, 1996, announced that McDonnell Douglas would stop buying parts from Loral for its jet fighters once Lockheed Martin acquired Loral. Paul Kaminski, the chief of procurement at the Pentagon, wrote to McDonnell Douglas, stating that this could '"increase the cost or lower the quality of the products you supply"' and that if the best product is offered by a given supplier, which '"happens to be Loral, then McDonnell Douglas should continue to buy from that company"' (Cole,1996).

Horizontal mergers, in the absence of viable international competition or entry by new companies, could lead to increased market power and higher prices in certain sectors. For example, one of the concerns with Raytheon's acquisition of Hughes Aircraft and the defense divisions of Texas Instruments in 1997 was that these acquisitions would provide Raytheon with a near monopoly position in spy satellite sensors, night vision equipment, and air-to-air missiles. Hughes and Raytheon had previously been strong competitors for missile contracts, and, according to the chief of acquisitions at the Pentagon, Paul Kaminiski, "their competition saved taxpayers hundreds of millions of dollars, shaving 70 percent from Hughes' original price." Raytheon, on the other hand, had argued that other companies had competed in missile competitions and had won, citing McDonnell Douglas' and Lockheed Martin's success in bidding for the JASSM missile contract (Mintz,1997).

On the other hand, consolidation might also lead to more innovative or less costly weapons systems due to greater pooling of knowledge between consolidating contractors. For example, Boeing, which had acquired Rockwell and McDonnell Douglas, succeeded over Lockheed in winning a $5 billion contract for a National Reconnaissance Satellite in 1999. At the time, some argued that the combination of knowledge and talent between McDonnell Douglas, Rockwell, and Boeing enabled the unified entity to win the contract and that this would not have been possible without consolidation (Flanigan, 1999). A second example is when the Navy in early September, 1997 thought that the proposed merger between Lockheed Martin and Northrop Grumman would have actually enabled Lockheed, which had a weaker background in building naval aircraft, to compete more effectively against Boeing in the competition for the new Joint Strike Fighter (Ricks & Cole, 1998). The merger, as discussed earlier, did not take place.

Consolidation activity also could lead to improved cost efficiencies from reduced overhead costs—combining duplicative facilities and corporate headquarters, rationalizing and reducing the workforce, pooling R&D funds, and more effectively using pre-existing capacity. Indeed, when the Lockheed-Martin Marietta merger took place in 1995, it was estimated that merging telecommunications operations, research divisions, and headquarters, would save $3 billion over the following five years (Mintz, 1994). Some of the mergers clearly failed to yield their projected saving, however. For example, Martin Marietta's 1993 acquisition of General Electric Aerospace had only yielded half of the expected cost savings three years later, according to the GAO (Foote, 1996). Two years after the union of Hughes Aircraft and General Dynamics' missile division in 1992, the Inspector General could not verify that the consolidation had saved the projected $600 million for the Pentagon (Korb, 1996).

Has the wave of defense mergers led to cost savings for DoD? According to the *Los Angeles Times* in October, 1999, “Almost a decade of consolidation in the defense industry has failed to deliver the benefits of lower costs for the Pentagon. And the mergers of the ‘90’s that were supposed to produce stronger and more innovative defense contractors have more often caused corporate indigestion” (Flanigan, 1999). Industry observers argued that innovation had suffered from the mergers, and that the companies had become too big and were expending significant effort in managing themselves (Flanigan, 1999).

The issue of whether DoD recognized cost savings from the wave of consolidation was further complicated by its decision to pay the restructuring costs of consolidation beginning in July, 1993, provided that certain conditions from the consolidation were met, such as that the projected savings from the restructuring would exceed the costs. Under the 1997 DoD Appropriations Act*,* projected savings needed to exceed costs by a ratio of two to one for business combinations occurring after September 30, 1996, in order for restructuring costs to be reimbursed (Cooper, 1997). In 1997, DoD calculated that, through September 30, 1996, for every $1.00 that it paid in restructuring costs, it estimated $1.93 in savings because it had paid $179.2 million in restructuring costs and realized savings of $346.7 million. Nevertheless, in several of the five business combinations reviewed, savings was much less than the contractors had actually estimated. For Lockheed Martin, the estimated savings used to certify the Lockheed-Martin Marietta merger as eligible for restructuring, as of September 30, 1996, was less than half of the savings estimate which had originally been projected (Cooper, 1997).

Analysis of Cost Data on Weapons Systems by Type and by Defense Contractor

This analysis examines whether cost estimates for weapons systems made by leading defense contractors increased or decreased following a merger with another major defense contractor. The analysis used cost data from the summary tables in the *Selected Acquisition Reports* (*SARS*) which are submitted to Congress by DoD and which report the acquisition costs of Major Defense Acquisition Programs (MDAPS).[5] Each *SAR* contains a variety of various items on the mission of the weapons system and the contractors involved, as well as data on the costs of the weapons system, including baseline cost estimates and quantity estimates, current cost estimates and quantity estimates, and a decomposition of cost changes into quantity cost changes, schedule cost changes, engineering cost changes, support cost changes, estimating cost changes, and other cost changes. The period covered in the *SAR* data used in this analysis encompassed March, 1981 until June, 2006.

The analysis examined 28 weapons systems/ programs; this is only a subset of the weapons programs available in the *SARS*. These systems were selected because: (a) the primary contractor was involved in a merger with a major defense contractor during the

[5] MDAP (Major Defense Acquisition Program)—“Defined in 10 USC § 2430 as a Department of Defense (DoD) acquisition program that is not a highly sensitive classified program (as determined by the Secretary of Defense) and that is designated by the Secretary of Defense as a major defense acquisition program, or that is estimated by the Secretary of Defense to require an eventual total expenditure for research, development, test, and evaluation of more than $365,000,000 (updated to FY 2000 constant dollars) or an eventual total expenditure for procurement of more than $2,190,000,000 (updated to FY 2000 constant dollars)” (Department of Defense, 2006, August 3).

period covered; (b) there was enough time series data to examine the pre-merger and the post-merger period; (c) the weapons system was only made for one of the services; and (d) the contract for the weapons system, during the period covered, did not have a defense contractor that was not involved in the merger as its primary contractor. The research is still ongoing, and it is expected that more weapons systems/ programs will be included in an expanded version of this preliminary study.

This analysis examines the current year cost estimates in base year dollars of each weapons system/program over time. This is because current year cost estimates in base year dollars capture overall pre- and post-merger effects better than other variables in the *SARS,* which decompose the cost change into quantity changes, schedule changes, engineering changes, etc. A merger could impact cost estimates through any of these avenues, so year-to-year changes in overall current year cost estimates in base year dollars provided the best measure. An expanded version of this preliminary study intends to examine the other components of the cost change decomposition in greater detail. Current year cost estimates in base year dollars were also used to minimize the impact of inflation.

The regression model used for each of the 28 weapons systems/ programs regressed current year cost estimates in base year dollars for a given weapons system on a time trend variable and on an indicator variable that took on the value of “1” after the merger of its primary contractor and “0” before the merger. The time trend controlled for the increases in cost estimates over time. The regression model appears below:

$$(\textit{Current year cost estimates in base year dollars})_i = \alpha + \beta_1\,(\textit{time trend})_i + \beta_2\,(\textit{post-merger indicator variable})_i$$

The regression was run over the time series data for each weapons system. In one set of regressions, the post-merger effect was assumed to take place beginning with the report date of the *SAR* nearest chronologically to the effective date of the merger. In the second set of regressions, the post-merger effect was assumed to take place beginning with the report date of the *SAR* which was the second nearest chronologically to the effective date of the merger. Although the timing of the impact of a merger on *SAR* cost estimates can vary between contractors and weapons systems, the analyses focused on the nearest *SAR* to the merger date or the second nearest *SAR* for consistency.

Tables 5 and 6 show that the empirical results are largely robust, regardless of whether the post-merger effect is assumed to occur beginning with the *SAR* nearest chronologically to the effective merger date or the second nearest *SAR* to the effective merger date. The first column includes the name of the weapons system; the second column gives the coefficient (and its sign) for the post-merger indicator variable; the third column provides the p-value for the statistical significance of the post-merger effect on cost estimates; the fourth column gives the coefficient (and sign) on the time trend, and the fifth column provides the p-value for the statistical significance of the time trend.

Table 5. Regression Results with the Post-merger Effect Beginning at the *SAR* Nearest to the Effective Date of the Merger

Weapons System	Coefficient on post-merger indicator variable	P-value on coefficient for post-merger indicator	Coefficient on time trend variable	P-value on coefficient for time trend variable

		variable		
AH-64	36.9611	0.763	47.257	0.000
AIM-9X	1554.8	0.000	4.8778	0.568
ASAS	-1419.66	0.000	16.395	0.046
AMRAAM	-2826.00	0.000	183.26	0.000
ATACMS	134.47	0.366	29.903	0.000
AV-8B	-113.64	0.001	6.5453	0.005
ATCCS	179.68	0.046	-12.833	0.003
ATICRM	-49.355	0.899	64.324	0.007
C-17	17687.66	0.000	319.77	0.000
DDG-51	-6357.78	0.001	740.82	0.000
FA-18	-21133.99	0.002	635.6	0.014
F-22	-8867.30	0.151	1074.1	0.000
Javelin	-78.669	0.840	14.043	0.291
JDAM	-669.47	0.032	147.651	0.000
JSOW	542.25	0.609	-9.9954	0.827
JSTARS	-1396.20	0.003	168.99	0.000
LHD-1	251.02	0.210	53.764	0.000
Longbow Apache	-381.75	0.612	149.51	0.000
Longbow Hellfire	-759.73	0.033	36.382	0.008
NAVSTAR User Equipment	-212.399	0.013	29.502	0.000
Titan IV	-9604.985	0.000	504.366	0.000
DMSP	15.714	0.322	6.557	0.000
FBCB2	-422.658	0.180	4.646	0.876
MLRS	-28.854	0.744	28.307	0.000
Strategic Sealift Program	58.530	0.685	20.624	0.029
T45TS	143.59	0.401	47.809	0.000
Trident	-2111.671	0.056	10.3506	0.679
JPATS	744.526	0.047	124.02	0.000

Table 6. Regression Results with the Post-merger Effect Beginning at the Second Nearest *SAR* to the Effective Date of the Merger

Lagged	Coefficient on post-merger indicator variable	P-value on coefficient for post-merger indicator variable	Coefficient on time trend variable	P-value on coefficient for time trend variable
AH-64	87.88	0.48	45.65	0.000

AIM-9X	1279.3	0.000	9.408	0.422
ASAS	-1004.9	0.002	-8.205	0.733
AMRAAM	-2953.6	0.000	184.6	0.000
ATACMS	234.6	0.108	27.20	0.000
AV-8B	-116.95	0.001	7.088	0.004
ATCCS	194.91	0.033	-13.60	0.002
ATICRM	255.64	0.504	49.295	0.031
C-17	17138.7	0.000	336.68	0.000
DDG-51	-7478.1	0.000	761.47	0.000
FA-18	-24329.8	0.000	751.15	0.003
F-22	-11220	0.067	1127.4	0.000
Javelin	1156.99	0.002	-22.196	0.067
JDAM	-698.65	0.028	149.39	0.000
JSOW	1631.28	0.126	-50.687	0.276
JSTARS	-1300.27	0.005	166.48	0.000
LHD-1	144.32	0.476	55.225	0.000
Longbow Apache	-669.24	0.372	158.10	0.000
Longbow Hellfire	-789.56	0.030	38.132	0.007
NAVSTAR User Equipment	-191.89	0.024	28.756	0.000
Titan IV	-10094.5	0.000	513.14	0.000
DMSP	30.865	0.041	5.910	0.000
FBCB2	-606.34	0.056	22.475	0.456
MLRS	-34.901	0.693	28.377	0.000
Strategic Sealift Program	93.856	0.506	19.345	0.028
T45TS	63.6989	0.707	49.373	0.000
Trident	-1489.63	0.178	-2.125	0.933
JPATS	947.42	0.006	118.27	0.000

Table 7 summarizes the findings of Tables 5 and 6. Again, there is little difference between the findings if the merger effect is assumed to begin at the *SAR* closest to the merger effective date and the findings if the merger effect is assumed to begin at the second nearest *SAR* to the merger effective date. Between 54% and 64% of the systems examined in the analysis experienced a statistically significant change in their cost estimates following a merger, controlling for the time trend. Between 39% and 43% of the systems experienced a statistically significant negative reduction in cost estimates in the post-merger period, controlling for the time trend, while between 14% and 21% of the systems experienced a positive, statistically significant cost increase. This suggests that defense mergers did not always experience a statistically significant change in their cost estimates post-merger but that, for those systems that did, the cost estimates were more likely to decrease than to increase, even controlling for the time trend.

Table 7. Percentage of Weapons Systems Experiencing a Post-merger Change in Cost Estimates

	Percentage of systems experiencing a positive and statistically significant change	Percentage of systems experiencing a negative and statistically significant change	Percentage of systems experiencing a statistically significant change
Post -merger effect begins at the *SAR* closest to the merger effective date	14.3%	39.3%	53.6%
Post-merger effect begins at the second nearest *SAR* to the merger effective date	21.4%	42.9%	64.3%

Table 8 summarizes the weapons systems findings from Table 6 and categorizes those results based on the type of weapons system classification found in the 1998 GAO report, although this analysis added the strategic electronics sector and the munitions sector. The classification of the weapons systems into these broader categories was done by examining the description of the weapons systems in the *SARS*, consulting *Jane's*, reading materials written by the defense contractors, examining *The 2007-2008 Weapons Systems* from the Office of the Assistant Secretary of the Army for Acquisitions, Logistics, and Technology, and reading detail on each system written by the Federation of American Scientists.

The categories which were most affected by the mergers in the sense that 80-86% of the weapons systems in those categories exhibited a statistically significant post-merger change in cost estimates were the strategic electronics category and the fixed-wing aircraft category. About 57%-60% of those systems exhibited a statistically significant reduction in cost estimates, controlling for the time trend. Based on the data in Table 4, the number of prime contractors in the fixed-wing aircraft sector experienced a 62.5% decline between 1990 and 1998. Consequently, this analysis suggests that although market concentration in the fixed-wing aircraft sector increased, this led to more significant cost decreases than cost increases in weapons systems. The evidence is less clear in the tactical missile category, in which, based on the data in Table 4, the number of contractors declined 69.2% between 1990 and 1998. About 57% of the weapons in the tactical missile category exhibited statistically significant changes in their cost estimates, of which 28.6% of them exhibited significant increases and 28.6% of them exhibited significant decreases. The number of prime contractors in the surface ships category declined 37.5%, but the only system in that category that manifested a significant change exhibited a cost decline. The analysis had fewer systems in the rotary aircraft, strategic missile, munitions, and satellite categories, but a subsequent expanded version of the analysis hopes to include more systems in these categories.

Table 8. Percentage of Weapons Systems Experiencing a Post-merger Change in Cost Estimates by Equipment Type

	Percentage of systems in each category which experienced a statistically significantly higher cost estimate post-merger	Percentage of systems in each category which experienced a statistically significantly lower cost estimate post-merger	Percentage of systems in each category which experienced a statistically significantly different estimate post-merger (higher or lower)
Rotary Aircraft AH-64 Longbow Apache	0%	0%	0%
Tactical Missile AIM-9X AMRAAM ATACMS Javelin JSOW Longbow Hellfire MLRS	28.6%	28.6%	57.1%
Strategic Electronics ASAS NAVSTAR User Equipment FBCB2 ATCCS ATICRM	20%	60%	80%
Fixed-wing Aircraft AV-8B C-17 FA-18 F-22 JSTARS T45TS JPATS	28.6%	57.1%	85.7%
Surface Ships DDG-51 LHD-1 Strategic Sealift Program	0%	33%	33%
Satellite DMSP	100%	0%	100%

Munition JDAM	0%	100%	100%
Strategic Missile Titan IV Trident	0%	50%	50%

Table 9 summarizes the results in Table 6 by defense contractor. Between 70% and 80% of the weapons systems made by Boeing, Raytheon, and Lockheed experienced statistically significant changes in their cost estimates following their mergers. Raytheon is the only one of the major contractors which had a higher percentage of weapons systems (60%) that experienced a statistically significant cost increase than the percentage of weapons systems (20%) that experienced a statistically significant cost decrease. Over half of the weapons systems made by Lockheed, General Dynamics, and Boeing experienced a statistically significantly lower post-merger cost estimate. As discussed earlier, by 1998, Boeing was one of the prime contractors in 6 of the 10 markets, and Lockheed Martin was one of the prime contractors in 5 of the 10 markets. Again, this evidence suggests that although these contractors were obtaining greater market share through their consolidation, the mergers were more likely to reduce cost estimates for the weapons systems than to increase them. Raytheon is the exception, but it was one of the prime contractors in only 2 of the 10 markets (as delineated by the 1998 GAO report) and so had less opportunity for market power than Lockheed Martin and Boeing.

Table 9. Summary of Statistically Significant Cost Changes by Defense Contractor

	Percentage of systems made by each defense contractor which experienced a statistically significantly higher cost estimate post-merger	Percentage of systems made by each defense contractor which experienced a statistically significantly lower cost estimate post-merger	Percentage of systems made by each defense contractor which experienced a statistically significantly different estimate post-merger (higher or lower)
Northrop	0%	40%	40%
Boeing	14.3%	57.1%	71.4%
General Dynamics	0%	50%	50%
Raytheon	60%	20%	80%
Lockheed	25%	50%	75%
McDonnell Douglas	14.3%	42.8%	57.1%

Table 10 explores the impact of the merger between Lockheed and Martin Marietta (effective on March 16, 1995) and the merger between Boeing and McDonnell Douglas (effective on August 1, 1997) on the weapons systems produced by these prime contractors for which sufficient data was available. The Lockheed-Martin Marietta merger impacted over 80% of the weapons systems examined, but 2/3 of them experienced a statistically significant decline in cost estimates, controlling for the time trend. The Boeing-McDonnell Douglas merger impacted 2/3 of the weapons systems examined, of which 50% of them experienced a statistically significant decline in cost estimates, controlling for the time trend.

Table 10. Impact of Selected Defense Mergers on Weapons Systems Cost Estimates

	Percentage of systems made by the defense contractors involved in a specific merger which experienced a statistically significantly higher cost estimate post-merger	Percentage of systems made by defense contractors involved in a specific merger which experienced a statistically significantly lower cost estimate post-merger	Percentage of systems made by the defense contractors involved in a specific merger which experienced a statistically significantly different estimate post-merger (higher or lower)
Lockheed / Martin Marietta **(March 16, 1995)** ASAS F-22 Longbow Hellfire Titan IV DMSP Trident	16.7%	66.7%	83.3%
Boeing/McDonnell Douglas **(August 1, 1997)** AV-8B C-17 FA-18 JDAM Longbow Apache T45TS	16.7%	50%	66.7%

Conclusions

This study examines evidence on the causes and the results of the defense merger wave of the late 1990s. Although the analysis is by no means exhaustive, it does suggest several key findings.

First, defense mergers are negatively correlated with DoD procurement outlays. The correlation between defense mergers in a given year and DoD procurement outlays in the previous year are stronger than correlations of measures in the current year. This suggests

that merger activity is more likely to be a delayed response to previous spending levels than to current spending levels.

Second, the correlations between defense merger activity and overall merger activity in the economy are strongly positive. On balance, the correlations between defense merger activity and overall merger activity are much stronger than the correlations between defense merger activity and DoD outlays. This suggests that merger activity was driven less by declines in spending following the Cold War, and more by a stronger economy and a vibrant financial market.

Third, the reduction in the number of prime contractors between 1990 and 1998 was more substantial in certain sectors than in others and resulted in some of the defense contractors becoming dominant across sectors. The tactical missiles, fixed-wing aircraft, and expendable launch vehicle sectors experienced a 2/3 reduction in the number of prime contractors during the period. The major giants which emerged from the consolidation were Boeing (one of the prime contractors in 6 of the 10 sectors), Lockheed Martin (one of the prime contractors in 5 of the 10 sectors), and Northrop Grumman (one of the prime contractors in 3 of the 10 markets).

Fourth, in examining the *SAR* cost data on 28 weapons systems, only 50-65% of them exhibited a statistically significant post-merger cost change, which suggests that many weapons systems' estimates were unaffected by the mergers. About 40% of the weapons systems examined in this analysis experienced a statistically significant decrease in cost estimates, controlling for the time trend, and about 15-20% of the systems experienced a statistically significant increase in cost estimates. This suggests that, to the extent that the weapons systems were impacted by mergers, a greater proportion of them experienced a reduction in costs rather than an increase in costs.

Fifth, when the weapons systems are classified into the 10 categories discussed in the 1998 GAO Report (with two additional categories), the fixed-wing aircraft, strategic electronics, and tactical missile categories had the highest percentage of systems which experienced a statistically significant post-merger change. Within the strategic electronics sector and the fixed-wing aircraft sector, about 60% of the systems experienced a statistically significantly lower cost estimate during the post-merger period. In the tactical missile category, 28.6% of the systems surveyed experienced a statistically significantly higher post-merger cost estimate and 28.6% of the systems experienced a statistically significantly lower post-merger cost estimate. This suggests that in the fixed-wing aircraft sector especially, which manifested a 2/3 decline in prime contractors between 1990 and 1998, the increase in market concentration did not result in higher costs for DoD. The findings were evenly split in the tactical missile category, which also experienced a 2/3 decline in contractors.

Sixth, when the weapons systems were identified with their primary contractor, between 70% and 80% of the weapons systems examined in this analysis which were produced by Boeing, Raytheon, and Lockheed experienced a statistically significant change in their cost estimates. For Boeing and Lockheed, 50-57% of the systems experienced a statistically significant reduction in cost estimates. Raytheon was the only contractor for whom 60% of the systems experienced a statistically significant increase in their cost estimates. This suggests that the increases in market power may not have translated into higher costs for DoD, especially for systems made by Lockheed and Boeing. Indeed, 2/3 of the systems made by Lockheed and Martin Marietta experienced a statistically significant

decline in cost estimates following the merger. Half of the systems made by Boeing and McDonnell Douglas experienced a statistically significant decline in cost estimates following their merger.

In conclusion, the analysis suggests that, although market concentration levels in certain sectors increased due to the wave of defense mergers, DoD's costs across weapons systems tended to be lower in the post-merger period. Although further research on a larger sample of weapons systems distributed across various sectors is necessary to more fully inform the public policy discourse, this study indicates that increases in market power do not necessarily lead to an anticompetitive outcome in pricing. Additional research on innovation cycles within the weapons systems is necessary, as well as a greater assessment of the degree to which international competition or the possibility of entry of smaller competitors in some of these sub-sectors constrained cost increases. Many of the questions and concerns in the earlier rounds of consolidation may emerge if a second round begins, possibly at a more global level, so an assessment of the strengths and weaknesses of the most recent round during the late 1990's is crucial.

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Strategic Sourcing—Is There a Role for Midsize Companies in the Industrial Base Supporting the Federal Government Market Space?

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Introduction

Strategic Sourcing has become the focus of buying organizations both in government and the private sector. In the federal government, the Office of Federal Procurement Policy (OFPP) began an initiative in 2004 through its Chief Acquisition Officer Council (CAOC) to provide for Strategic Sourcing on a government-wide basis. Similarly, State and Local governments have initiated strategic sourcing initiatives to varying degrees across the United States. In support of this initiative, the National Institute of Governmental Purchasing (NIGP) adopted a resolution in 2006 supporting the use of Strategic Sourcing at levels of government. In the private sector Strategic Sourcing has been a way of life now for over a decade.

For the uninitiated, Strategic Sourcing has become synonymous with the process of identifying certain commodities, or commoditizable [sic] services, aggregating those commodities, and then driving a price point that reflects the leveraged buying power of a particular buying organization. While this certainly reflects an aspect of Strategic Sourcing, Strategic Sourcing is much broader and encompasses not only the actual sourcing decisions, in terms of aggregation of requirements and supplier/supply-chain management, but also the analysis of all requirements, the capabilities of the supplier base to meet those requirements, and the appropriate method to satisfy requirements through the supplier base, among other considerations. In some cases, managing the supplier base/supply chain requires the identification of the optimum size of the supplier base/chain and the mix of companies (read capabilities) necessary to meet the demands of the buyer. On occasion, the management of the supplier base/chain includes, or should include, efforts to expand or contract the base, or the mixture within the base, in order to control value and the total cost of ownership to the buyer. The ability of a buyer to shape the base is dependent on the buyer's buying power and, in the case of governmental buyers, other policy considerations associated with the functions of a sovereign. It is from this latter perspective that we

[6] The opinions expressed herein are solely those of the author. They do not reflect the opinion of the US General Services Administration or the US government.

approach the question of this paper of whether there is a role for midsize companies in the base/market that supports government acquisition at the federal, state and local levels.

Market Shares of Smalls, Midsize and Large Companies

At the moment, the absence of an accepted definition for midsize companies makes it impossible, with any precision or general acceptance, to define the market share for midsize companies. In fact, the current statutory and regulatory schema divides markets into two groups, small companies and other than small companies. Small companies are defined by statute and regulation in the federal market and in most state and local markets. Even where small companies are defined by statute and regulation, there is room for inaccuracy precisely because of the way in which the definitions are drafted and as result of evolution in the markets themselves. For example, the size status of a company in the US federal market is determined by the North American Industrial Classification System (NAICS), which establishes size status based on the code selected. The various codes use one of two, or a combination thereof, measurements to determine the size of a company: sales or the number of employees. Because the federal contracting officer determines the NAICS code to employ in a particular acquisition, in some acquisitions a company may be small and in others, other than small. In addition, in the federal market, there are process rules that allow a company to remain small for reporting requirements for the duration of a contract, even though after submission of their original offer an event occurred that caused the company to become other than small.

It has often been argued that there is a strong strategic and economic benefit in encouraging small business in America. The Small Business Administration (SBA) anticipates that small businesses will be responsible for the nation's economic growth during the coming decades, however, at great risk to the companies themselves. The key role of small enterprises in the federal market space has further been codified through the *Small Business Act* established by Congress. The purpose of the *Act* is to provide assistance to these ventures through set-aside programs, sole-source contracting opportunities, interest-free loans and a variety of government funding and support activities.

In the information technology (IT) arena, the welfare of small and midsized companies is critical to the US economy in that the birthplace of innovation generally is found in small to midsized businesses, and the new technologies will open avenues for future investment, growth and employment opportunities for the future. While it may be true that large companies have an innovative advantage in sectors that are capital-intensive, highly unionized and specialized, small businesses have the innovation advantage when skilled labor comes into play (Acs & Audretsch, 1987). Secondly, in order to remain competitive in the global marketplace, the US needs to constantly feed and foster new product development.

By most reports, the federal government's SBA is serving its constituents well. Marked growth in some industries, especially those whose market sector has expanded into global commerce via the Internet, has catapulted the previously categorized small business into the midsize sector. The IT market has especially fallen prey to this phenomenon since the late 1990s. What would appear to be a boon for these corporations often becomes detrimental to their existence. The intended protectionism provided by the *Small Business Act*, one that allowed for a gradual, steady growth of a business, one under which experience can be gained and expansion revenue generated, is then lost by the sudden

influx of economic success without the insight and wisdom of years of business-management knowledge.

Once the threshold of success has been crossed for a company that has morphed from small to midsize, a series of events occur. This maturation of the enterprise ends the exemption provided to small business in such areas as cost accounting reporting and governmental contracting compliance standards. These emerging enterprises have a greater need for capital for expansion, and most often the small business has been reliant on the credit of an individual such as the owner for ready cash. As the small business market grows into midsize success stories, the risks associated with achievement are exponentially multiplied though regulatory requirements, technology exposures and environmental threats. A great deal of companies report that they are having difficulties getting financial software systems that will meet the growing needs of their enterprise at a price that is affordable to the midsize market. This exemplifies the challenge of finding something stronger than Quicken but smaller than SAP (large-corporation ERP system) for their finances. Unfortunately the dummied-down versions are not available in the mid-market size. This begs the question of just who are small, midsize and large businesses.

Defining Small, Midsize and Large Businesses

In the market generally, small businesses are viewed by the public as those companies that have less than 100 employees and no more than $500K in annual sales (Peterson, Albaum, & Kozmetsky, 1986). This general interpretation by the average citizen differs from that of the Small Business Administration’s standards of a maximum of 500-1,500 employees based on industry type, and average annual sales as high as $17 million (Small Business Administration, 2006).

In the management accounting software realm, the middle market segment is defined as companies who have $1 million to $250 million in annual sales—the number of employees is not mentioned as the regulations and accountability of such revenue dictates the level of sophistication needed in product development and application.

What is a Midsize Company?

As noted earlier, while there are definitions for small businesses in the federal market and in most state and local markets, there is no generally accepted schema for identifying midsize companies. There clearly is no agreement on how a company’s size should be measured, e.g., number of employees or sales (gross or net). Further, there is an even greater divergence of opinion at what point a company other than small becomes a large business in terms of number of employees or sales (gross or net). For the purposes of this discussion, we would like to posit that the definition should be tied to the gross sales of the company as opposed to the number of employees.

We suggest the use of gross sales as a measure for midsize companies. We do so in no small part as a reaction to how the markets have evolved over the past several decades. At one point in time, companies integrated their functions horizontally—performing most of the work they sold within their own employees. Over the past decades, companies in both the manufacturing and service sectors have, to a great extent, outsourced non-core functions of their business, keeping as members of their in-house workforce only those employees key to the core functions, and relying on outside sources to

"ramp" up to meet business engagements. Using the number of employees a company has in this environment grossly under appreciates the share of the market a company may actually control, whereas gross sales really tell the story of a company's dominance in a particular market sector.

In terms of what threshold should be used to determine the size of a company other than small, the suggested numbers are all over the map. The US General Services Administration (GSA), in preparing a Request for Proposal (RFP) for its next generation Government-wide Acquisition Contract (GWAC) (named Alliant), issued a Request for Information (RFI) from the IT industry (hardware, software and services) asking for feedback from the industry on what the cutoff should be in terms of sales for a midsize company in that market. GSA received a significant amount of feedback from companies with recommendations ranging from $500 million dollars in sales and up; Yet, the majority of those responding proposed $500 million in sales as the threshold.

For purposes of this paper, we recommend that the definition be set at $500 million in gross sales. Over time, in keeping with sound Strategic Sourcing practices, this threshold should be reviewed and adjusted as the nature of the market changes. It may also prove necessary, as the SBA found for small businesses, to adjust this threshold market by market based on specific market conditions. Clearly, this would prove a significant effort to undertake; yet, its continual maintenance is essential to achieve sound market management to meet government buyer requirements.

The Importance of Midsize Companies to a Healthy Government Market—Size Really Does Matter

What happens when a business outgrows its competitors and is forced to compete with the "big dogs" for the first time—when they are too big to be small and too small to be big? A company in this transitional phase of moving from small to large is considered to be in "no-man's land." It is here that they have maximized the ability of their founders to further add capacity to the business, while at the same time burning cash in order to keep up with the market. Additionally, when a new midsize business loses a major client it had been serving during its evolution, the impact of such a loss can devastate or perhaps destroy the company entirely (Lafayette, 1992).

Most small business owners sacrifice themselves for the betterment of the business, putting in long hours and taking little pay for their efforts. Often, they rely on the skills of the founder, and when capacity dictates additional support, they find that they must pay a prevailing wage for the work, thus taking in lower profits.

Along with the additional resources needed to keep up with demand comes the burden of growing customer expectations. What a small business did to cater to its customers (from personalized service, friendly conversations and lunch meetings) will not only be expected to continue as the firm grows, but increasing levels of service will be anticipated: "Now that the business has all that money from expansion, well surely they could have house-calls, and free replacements, etc."

At the crux of this explosion of opportunity will be the requirement for the owner to give up his control of the company. A CEO, CFO or COO will be needed, and this is not a small investment to be had. You can't manage a larger company without a high-level

manager; but as a midsize business, you may not be able to afford their services. Thus the term "no-man's land."

Cold Hard Cash

As the personal net worth of the founder becomes tied to the company's balance sheet, the credit of the company becomes risky. There appears to be a reluctance to borrow money, as repayment causes lower profit margins—already very tight due to the competitiveness of the marketplace (*Journal of Commerce*, 1999, January). When money is needed and funds are hard to come by, this is when the decision to seek venture capital comes into play. Control of the corporation by these investors often leads to the separation of the founder from the business he/she founded. Further, it may be that the successful midsize business is just the perfect complement to the large corporation seeking to acquire a greater market share and lock-in or -out its competition. In the end, most midsize companies vanish into either a subdivision of a larger entity or disappear completely through dissolution.

Better, not Bigger

Some companies, when faced with the challenge of expansion, have discovered that perhaps the growth opportunity is not worth the investment, thus choosing to be better and not bigger. These companies look at the market sector in which they operate and choose to perfect their niche—moving from good to great and staying in control of their own destiny. In situations such as these, the most important motivators for the company are found not in profit generation, but in relationships that have been built, ties that have been created in a community and the personal rewards that have generated from the worthwhile work they perform (Burlingham, 2006).

Challenges for the Midsize

In order to be successful, midsized companies must be able to foresee the requirements of their clients and find innovative methods with which to meet these needs. A constant stream of investment must always be made in which cutting-edge thoughts and actions are encouraged (Violino, 2006). Companies that fail to take action in these areas tend to fail, and the failure to keep up with the impact of IT innovations can really play a critical role in the downfall of a successful company. The Internet has had a profound impact on companies that found a manner in which to incorporate the opportunity of increased exposure, high demand and customer service. Those businesses that chose to ignore the digital revolution are now awakening to a business model that fails to meet the new consumer set of expectations.

Risk Tolerance

The amount of risk tolerated by companies is often dictated by their size and market position. Large companies tend to be as bureaucratic and risk averse as governmental organizations. Even where they are inclined to take risk, their internal processes to identify the risk, quantify the risk and get approval to assume it are lengthy and expensive. Clearly, when a large company decides to assume risk, they price for it in an attempt to shift as large a portion as possible to the buyer. Conversely, small companies generally lack the

bureaucracy associated with making risk-assumption in large businesses; but when they face the “bet the company” type of risk issues, their inability to shift the risk through pricing or to bet the company’s fate on a single acquisition may cause them to pass on acquisition. Midsize companies are particularly situated in this risk-tolerance arena to take on the risk without having to bet the company or the ability to fully shift the risk to the buyer through pricing. The buyer clearly benefits in this environment.

Integration

Another arena where midsize companies provide an advantage is integration. More and more today government buyers find themselves in situations in which they lack the expertise to serve as integrator for solutions they require, but feel uncomfortable buying the products and services and integration function from a single provider. Small companies will frequently lack expertise in integrating these complex requirements, although they are more than capable of providing the products or services or both. Large companies are capable of providing a fully integrated solution, but experience has shown that it may be to the buyer’s advantage to separate the integration function from the parts to be integrated to create a tension in the supply chain that ensures that decisions are made that ultimately benefit the buyer while focusing on performance and cost-benefit trade-offs.

Overhead Costs

Clearly, an advantage that midsize companies offer (whether in fixed-priced or cost-type acquisitions) is lower overhead rates. Small businesses offer similar advantages in this area as well. Lower overhead costs benefit the buyer in both fixed-price and cost-type contracts.

Flexibility/Responsiveness

The advantages in flexibilities and responsiveness, at least from an organizational perspective, are clear to any observer when dealing with midsize companies. With large companies, try calling the President or CEO of the company as a government buyer and getting them on the phone; our personal experience has been that even when calling to discuss potential suspension or debarment (the equivalent of the death penalty in government contracting), getting through to a Large company’s senior executives to talk is difficult at best. However, at the midsize level, the very nature of the organization allows/promotes effective communication with the company’s senior executives.

Similarly, when problems arise, even the best contracts with the best companies of all sizes have problems; midsize companies seem to demonstrate greater flexibility. Whether this flexibility stems from the lack of a significant internal bureaucracy, greater risk tolerance, relative position in the market or some other reasons, is irrelevant. For the government, it means access to senior management and more timely, effective dispute resolution.

Boom and Bust Cycle

Finally, there is a boom and bust cycle in government marketplaces. Government at all levels promotes the development of small businesses and supports their growth through

programs designed to help them grow in size and gain experience in performing work. However, once they graduate to "other than small" in the US market, the government support network disappears completely, leaving most of these companies in the situation where they lack the government support programs to sustain their continued growth and, as noted above, the capital to compete with large companies. Thus, many either find themselves selling their company or going out of business. This is an incredibly wasteful process in which the company that the government invested in when it was small because it was the strongest part of the engine of our economy both in terms of producing jobs and in terms of technology development, patent submissions, etc., simply goes away—and along with it, often the jobs it created, the innovation it promoted and the experience acquired during the time it enjoyed the protections of the various small business programs. By identifying a mid-tier in the market and managing that tier so companies do not have to sell or go out of business, waste is eliminated and an overall stronger economy results—one better capable of surviving market shifts.

Conclusion

There is unquestionably a dearth of empirical data to support the suggestions in this paper. The dearth exists not because the data isn't available but because government markets have not focused on it to date. Intuition informs many that there is an important role for midsize companies in meeting the requirements of the government market, particularly in the challenging times facing government buyers today both domestically and internationally.

Midsize companies offer lower cost solutions, greater risk tolerance and more responsiveness than large companies; combine that with greater experience than small companies have had the opportunity to garner, and it is clear that there is a value to the government buyer in having midsize companies in the government market place… Government buyers, however, lack the empirical data they need to utilize existing procurement flexibilities to manage government markets to ensure that a sufficient number of midsize companies remain available to meet government requirements.

What is needed at this point is greater study of the markets, empirical demonstration of the value of midsize companies to those markets and then the development of an effective program designed to ensure that a sufficient mix of companies exist to meet the government's requirements in a timely manner and at best value.

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Panel 4 - Organizational Behavior in Acquisition Organizations

Wednesday, May 16, 2007 11:15 a.m. – 12:45 p.m.	**Panel 4 - Organizational Behavior in Acquisition Organizations**
	Chair: **Chair: Kenneth E. Miller**, Special Assistant for Acquisition Governance and Transparency to the Secretary of the Air Force **Papers:** ***Self-leadership and Creativity Differences in Line and Supervisory Defense Acquisition Employees*** **Trudy C. DiLiello** and **Jeffery D. Houghton**, Defense Acquisition University ***Acquisition Community Team Dynamics: The Tuchman Model vs. the DAU Model*** **Pamela Knight**, Defense Acquisition University ***The Relationships between Work Team Strategic Intent and Work Team Performance*** **Thomas R. Edison**, Defense Acquisition University

Chair: Kenneth E. Miller, a member of the Senior Executive Service, is Special Assistant for Acquisition Governance and Transparency to the Secretary of the Air Force, Washington, D.C. Mr. Miller assists in discharging the responsibilities in the direction, guidance and supervision of Air Force programs for research, development and acquisition of systems, supplies and services. This includes the formulation of acquisition and contracting policies and the management oversight of specific acquisition programs.

Mr. Miller, a native of Columbus, Miss., began his professional career in 1975 as an aerospace engineer with the Naval Air Systems Command. He advanced to weapons systems acquisition management as the Assistant Deputy Program Manager for the H-3 antisubmarine helicopter, later serving as Deputy Program Manager for the E-6A and Principal Deputy Program Manager for the A-6/EA-6 Weapons Systems Program Office. In April 1989, the Navy established the new Program Executive Offices within the acquisition system. Mr. Miller was selected to be the first Deputy for Acquisition for the Program Executive Office (Tactical Aircraft), providing policy and execution advice to the Program Executive Officer on assigned programs.

Mr. Miller was appointed to the Senior Executive Service as the second Deputy Program Executive Officer for Tactical Aircraft Programs, providing advice on acquisition-related issues for a variety of aircraft and weapons programs. In 1994, he was selected as the Assistant Commander for Corporate Operations, where his responsibilities included the strategic planning and corporate business functions of the Naval Air Systems Command. Additional duties included Chief Information Officer. In 1998, he was appointed Principal Assistant for Acquisition, Programming and Budgeting for the Director of Air Warfare within the Office of the Chief of Naval Operations. Mr. Miller was later

selected as the Assistant Deputy, Chief of Naval Operations, Warfare Requirements and Programs, defining and developing a variety of warfare requirements for the Department of the Navy. He is a frequent speaker at government, industry and national forums.

Self-leadership and Creativity Differences in Line and Supervisory Defense Acquisition Employees

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Abstract

This study investigated the relationships between self-leadership and creativity in the context of a defense acquisition organization. More specifically, this study examined differences in self-leadership, creativity and perceived organizational support for creativity between line and supervisory defense acquisition employees. Our analyses suggested that self-leadership was significantly related to creative potential and practiced creativity for both line and supervisory employees, although there were no significant differences in overall levels of self-leadership between the two groups. In addition, we found significant differences in creative potential, practiced creativity, gap scores and perceptions of organizational support for creativity. Specifically, line employees reported significantly lower levels of creative potential, practiced creativity and perceptions of organizational support for creativity along with higher gap scores in comparison to supervisors.

Our findings imply that self-leadership is a primary tool for facilitating creativity at all organizational levels and that active organizational support for creativity may be the key for reducing the gap between creative potential and practiced creativity that represents untapped creative resources. Our results suggest that this gap is much more pronounced among line employees and that line employees generally perceive less organizational

support for utilizing their creative resources than supervisors. In response, we make some specific suggestions for organizational interventions designed to increase self-leadership capabilities at all levels and to increase perceptions of organization support for creative practices among line employees in defense acquisitions. A workforce with creative self-leaders could synergistically assist organizations in maximizing the utility of all organizational resources.

Introduction

Innovation and creativity are critical for organizations to thrive in the 21st century (Kanter, 1983; Tushman & O'Reilly, 1997; Utterback, 1994). Indeed, the Office of Force Transformation (OFT) under the Office of Secretary of Defense (OSD) has placed the leveraging of innovation and creativity among the most effective approaches for creating the transformational changes needed to maintain the Department of Defense's strategic position. Creativity is more likely to occur if an individual has certain characteristics or innate skills and abilities (Tierney & Farmer, 2002; Hinton, 1970; Simonton, 1992; Woodman & Schoenfeldt, 1989) and when the individual perceives that the work environment supports creativity (Amabile, 1996; Cummings, Hinton & Gobdel, 1975; Woodman, Sawyer & Griffen, 1993). Furthermore, the ability to leverage creativity depends largely on effective leadership (Kouzes & Posner, 1995; Manz & Sims, 2001). A common theme in improving leadership effectiveness concerns knowing and leading oneself (Bennis, 1994; Drucker, 1999; Goleman, Boyatzis & McKee, 2002; Senge, 1990; Yukl, 2002). Self-leadership is a concept that focuses on self-reflection and evaluation aimed at improving personal and professional performance.

Although theorists have often suggested relationships between self-leadership and creativity (e.g., Kouzes & Posner, 1995; Manz & Sims, 2001), very little attention has been given to how these relationships may differ across organizational levels. The purpose of the current study is to examine the self-leadership and creativity differences in line and supervisory defense acquisition employees. The differences identified in this research may have important implications for maximizing employee self-direction and for fully utilizing creative resources at all organizational levels.

Creativity and Self-leadership

Although creativity is a complex concept that is somewhat difficult to define, consistent themes tend to emerge across the various definitions in the creativity literature (e.g., Barron & Harrington, 1981; Guilford, 1950; Martindale, 1989; Sternberg & Lubart, 1999). Based on the common ideas in these definitions, we define creativity as an ability to harvest novel but appropriate ideas in order to maximize efficiencies, solve problems, and increase effectiveness. We further divide the creativity concept into creative potential and practiced creativity (e.g., Hinton, 1968; DiLiello & Houghton, 2006, 2007). In short, if an individual's creativity is attenuated by the environment, then the individual will not utilize his or her full creative potential (Hinton, 1968; George & Zhou, 2001; Scott, 1965).

Creative potential is the creative capacity, skills and abilities that a person possesses (Hinton, 1968, 1970). Creative potential includes the concept of creative self-efficacy, an individual's subjective assessment of their personal ability to be creative (Tierney & Farmer, 2002). Creative self-efficacy involves seeing oneself as being good at creative problem-solving and generating novel ideas. Creative potential also includes having the talent or

expertise to do well in one's work and possessing the ability to take risks by trying out new ideas (Amabile, Burnside& Gryskiewicz, 1999).

Practiced creativity, on the other hand, is the perceived opportunity to utilize creativity skills and abilities. Practiced creativity should not be confused with creative performance, which is an external assessment of products or achievements (Amabile, 1996; Hinton, 1968). Practiced creativity is also different from the concept of organizational support for creativity, which is the extent to which, "an organizational culture […] encourages creativity through the fair, constructive judgment of ideas, reward and recognition for creative work, mechanisms for developing new ideas, and active flow of ideas, and a shared vision of what the organization is trying to do" (Amabile et al., 1999, p. 15). Employees with strong creative potential are more likely to actually practice creativity when they perceive strong support from the organization (DiLiello & Houghton, 2006); several key conditions must be present within an organization for its work environment to support individual creativity (e.g., Amabile, 1988; Ford, 1996; Mumford & Gustafson, 1988).

The distinction between creative potential and practiced creativity is important because when people perceive themselves as having creative potential but do not perceive the ability to use or practice this potential, they will be less likely to engage in creative behavior. The gap between creative potential and creative practice represents untapped organizational resources. Identifying such untapped resources may be especially important in defense acquisition organizations that are continually being told to "do more with less."

Self-leadership (e.g., Manz, 1986; Neck & Houghton, 2006; Neck & Manz, 2007) is a self-evaluation and self-influence process through which individuals identify and replace ineffective behaviors and negative thought processes with more effective behaviors and positive thought processes, thereby enhancing personal accountability and improving professional performance. Theorists have long suggested that leaders in organizations should encourage their followers to lead themselves in the workplace (e.g., Manz & Sims, 1980, 2001). Supervisors and work environments only have a limited control over the workers; additional control or work motivation must come from within the individual (Herzberg, Mausner & Snyderman, 2003; Manz & Sims, 1980; Sergiovanni, 1992). When employees are trained and empowered to lead themselves, supervisors can shift their focus from detailed oversight and control to longer-term, big-picture issues.

Founded upon several classic theories of self-influence—including self-regulation (Kanfer, 1970; Carver & Scheier, 1981), self-control (Cautela, 1969; Mahoney & Arnkoff, 1978, 1979; Thoresen & Mahoney, 1974), intrinsic motivation theory (e.g., Deci & Ryan, 1985), and social cognitive theory (e.g., Bandura, 1986)—self-leadership is a normative model that prescribes specific sets of behavioral and cognitive strategies aimed at increasing individual performance. Self-leadership strategies are often divided into three primary categories: Behavior Focused Strategies, Natural Reward Strategies and Constructive Thought Strategies (e.g., Neck & Houghton, 2006).

Behavior Focused Strategies involve identifying and replacing ineffective behaviors with more effective ones through a process of self-observation, self-goal setting, self-reward and self-correcting feedback (Neck & Houghton, 2006). Self-observation entails a close examination of one's own behaviors in order to identify behaviors that should be changed, enhanced or eliminated (Mahoney & Arnkoff, 1978, 1979; Manz & Sims, 1980; Neck & Manz, 2007). Once target behaviors have been identified, individuals can establish goals and associated reward contingencies to energize and direct necessary behaviors (Mahoney & Arnkoff, 1978, 1979; Manz & Sims, 1980; Neck & Manz, 2007). Additionally, self-

correcting feedback, consisting of a positively framed reflection on failures and undesirable behaviors, may be quite effective in helping to recast these behaviors in more positive directions (Manz & Sims, 2001).

Natural Reward Strategies include the ability of the individual to find pleasure in the work that has to be performed and to focus on the inherently enjoyable aspects of task or activity, leading to increased feelings of competence, self-control and a sense of purpose (Csikszentmihalyi, 1996; Deci & Ryan, 1985; Herzberg, Mausner & Snydermanl, 2003). Natural reward strategies include building more pleasant and enjoyable features into a task or activity so that the task itself becomes more intrinsically rewarding, and shifting mental focus to inherently rewarding aspects of the task (Neck & Houghton, 2006; Neck & Manz, 2007).

Constructive Thought Strategies focus on directing and reshaping various mental processes—including beliefs and assumptions, self-verbalizations (self-talk), and mental imagery—in order to create constructive thought patterns and habitual ways of thinking that may have a positive impact on individual performance (Neck & Houghton, 2006; Neck & Manz, 1992, 1996). For example, individuals can assess their thought patterns in an effort to identify and eliminate dysfunctional beliefs and assumptions with more rational and constructive ones (Burns, 1980; Ellis, 1977; Neck & Manz, 1992). Similarly, self-talk, defined as what we covertly tell ourselves, can be closely examined in order to eliminate undue negativity and pessimism. Research in various fields (sports psychology, clinical psychology, education and communication) supports the use of positive self-talk as an effective way to improve individual performance (e.g., Neck & Manz, 1992). Mental imagery involves symbolically experiencing behavioral outcomes prior to actual performance without overt physical muscular movement (Driskell, Copper, & Moran, 1994; Finke, 1989; Neck & Manz, 1992, 1996). Research suggests that people who visualize successful performance before actually engaging in performance are much more likely to perform successfully when faced with the actual task (Neck & Houghton, 2006). In a meta-analysis of 35 empirical studies, Driskell et al. (1994) reported an overall positive and significant effect for mental imagery on individual performance.

Theorists have often suggested a relationship exists between self-leadership and creativity (e.g., DiLiello & Houghton, 2006; Houghton & Yoho, 2005; Manz & Sims, 2001). The relationship between creativity and self-leadership may be partially founded on the concepts of autonomy and self-determination. Autonomy, a key aspect of creativity (e.g., Amabile, 1996; Barron & Harrington, 1981; Woodman et al., 1993), has been linked to self-determination and intrinsic motivation (Deci & Ryan, 1985). Self-determination is a primary component of self-leadership’s natural reward strategies (Neck & Manz, 2007). Indeed, empirical research suggests that an individual’s need for autonomy can subsequently influence the extent to which the individual engages in self-leadership (Yun, Cox, & Sims, 2006).

Other relationships between creativity and self-leadership have also been suggested. For example, Houghton and Yoho (2005) have suggested a relationship between individual self-leadership and subsequent levels of individual independence and creativity. In addition, internal locus of control, a theorized component of creativity, has been empirically related to individual self-leadership (Kazan & Earnest, 2000). Finally, an empowering leadership style (leading others to be self-leaders) tends to promote creativity rather than conformity (Manz & Sims, 2001). Indeed, creativity may be one of the most essential aspects of effective organizational leadership (Mumford & Connelly, 1999). Creative thinking and a different style of leadership are necessary to provide flexibility, facilitate change and redesign traditional bureaucratic processes (Katz & Kahn, 1978). Encouraging self-leadership is a

relatively new leadership style that may help to promote an organizational climate that supports creativity. Empowering leadership is rapidly becoming a key success strategy in the rapidly changing work environments of the 21st century.

The purpose of the current study is to examine the relationships between self-leadership and creativity in the context of a defense acquisition organization. More specifically, we will examine possible differences in self-leadership, creativity and perceived organizational support for creativity between line and supervisory defense acquisition employees. The present study will contribute to the self-leadership and creativity literature in a number of important ways. First, this study will take an empirical step toward understanding the nature of the relationship between self-leadership and creativity. This study will also examine the role of organizational support in facilitating practiced creativity among organizational members. Most importantly, this study is among the first to examine differences in self-leadership, creativity and perceptions of support between line and supervisory employees. Understanding these differences may be a critical for reducing the gap between creative potential and practiced creativity in organizations. Finally, this study makes a unique contribution to our knowledge of creativity and self-leadership in the context of defense acquisitions. The differences examined here may have important implications for creating a defense acquisitions workforce with strong self-leaders working in environments that support creativity. Creative self-leaders could synergistically assist the DoD in maintaining an all-important competitive advantage in the face of a wide range of 21st-century challenges.

Method

Sample and Procedure

Primary data were collected from the Army Contracting Agency (ACA) as part of a larger study that examined a number of performance-related issues. Approximately 37% of the total ACA workforce of approximately 1900 people chose to complete the online survey, a fairly high response rate when compared to the response rates for other federal employee surveys and to response rates for e-mail surveys in general (Sheehan, 2001). Listwise deletion for missing data resulted in a final overall sample of 654. This sample was subsequently divided into two subsamples (i.e., supervisory employees, N=215; and line employees, N=439) for further analysis. The average age of the respondents was approximately 46, and the average job tenure was approximately 12 years. Sixty percent of the respondents were female. The online survey was activated in accordance with the tailored design method (Dillman, 2000). An initial e-mail was sent to ACA workforce members that included an Informed Consent Notification, the purpose of the study, the approval and sponsorship of the study, a confidentiality statement and a link to the online survey. A subsequent follow-up e-mail summarized the first message, added a personal note and provided a four-day extension, along with a link to the online survey.

Measures

Thirteen items from the Revised Self-leadership Questionnaire (Houghton & Neck, 2002) were used to measure self-leadership. Twelve items were utilized to measure creativity: six items assessing creative potential and six items representing practiced creativity. These items have demonstrated fairly good reliability and validity for measuring creative potential and practiced creativity (DiLiello & Houghton, 2007). Perceived organizational support was measured with six items from “Keys: Assessing the Climate for

Creativity," used with the permission of the Center for Creative Leadership (Amabile et al., 1999). All items were measured utilizing a five-point Likert-type scale ranging from Strongly Agree to Strongly Disagree.

Analyses

Mean differences between supervisory and line employees for self-leadership, creative potential, practiced creativity, a gap score (i.e., the difference between creative potential and practiced creativity that represents untapped creative potential), and perceptions of organizational support for creativity were examined using a series of t-tests. In addition, a series of regression analyses were conducted to examine the effects of self-leadership, perceived organizational support for creativity and organizational level (line vs. supervisory) on creative potential, practiced creativity and gap scores, respectively, along with the effects of organizational level (line vs. supervisory) on perceived organizational support for creativity.

Results

Means and standard deviations for both supervisory and line employees for self-leadership, creative potential, practiced creativity, gap scores and perceived organizational support for creativity are shown in Table 1. The analysis indicated no mean difference between groups for self-leadership, $t(507) = 1.16$, $p = .247$. In contrast, analyses showed significant mean differences between the two groups for creative potential, $t(652) = 3.30$, $p = .001$; practiced creativity, $t(469) = 7.48$, $p = .000$; gap scores, $t(471) = -5.03$, $p = .000$; and perceived organizational support for creativity, $t(652) = 3.21$, $p = .001$.

Table 1. Means and Standard Deviations (in parentheses)

	SL	CP	PC	GS	OS
Supervisors	49.55	25.47	23.58	1.89	20.00
***N* = 215**	(6.10)	(2.98)	(4.04)	(4.10)	(5.40)
Line Employees	48.92	24.65	20.97	3.68	18.54
***N* = 439**	(7.43)	(3.03)	(4.51)	(4.60)	(5.46)

Note: SL=Self-Leadership, CP=Creative Potential, PC=Practiced Creativity, GS=Gap Score, OS=Perceived Organizational Support.

Four separate regression analyses were conducted. Model 1 examined the effects of the independent variables self-leadership and organizational level (1=supervisor - 0=line, using dummy variable coding) on the dependent variable creative potential. Model 2 examined the effects of self-leadership, perceived organizational support for creativity, and organizational level on the dependent variable practiced creativity. Model 3 examined the relationships between the three independent variables and gap scores. Finally, Model 4 explored the effects of organizational level on perceptions of organizational support for creativity. A summary of the results of these analyses is presented in Table 2.

The regression equation for Model 1 suggested that both self-leadership and organizational level were significantly related to creative potential, with self-leadership as the stronger predictor of the two (Standardized $\beta = .356$, $p = .000$). The equation for Model 2 indicated that self-leadership, perceived organizational support for creativity and

organizational level were all significant predictors of practiced creativity, accounting for approximately 42.6% of its variance. Of the three variables, perceived organizational support was the stronger predictor of practiced creativity (Standardized β = .563, *p* = .000). The Model 3 analysis found that perceived organizational support and organizational level were significantly and negatively related to gap scores, explaining approximately 33.1% of the observed variance. The regression equation suggested a strong negative effect for perceived organizational support (Standardized β = -.551, *p* = .000), indicating that lower perceptions of organizational support for creativity will result in larger gaps between individuals' creative potential and their practiced creativity. In addition, the equation suggests that gap scores will be significantly greater for line employees than for supervisors (Organizational Level: Standardized β = -.117, *p* = .000). Finally, the regression analysis for Model 4 implied that supervisors tend to have more positive perceptions of organizational support for creativity than line employees

(Organizational Level: Standardized β = .125, *p* = .001

Table 2. Summary of Regression Analyses Results

Independent Variables	Model 1: *β*	Creative Potential *p* - value	Model 2: *β*	Practiced Creativity *p* - value	Model 3: *β*	Gap Score *p* - value	Model 4: *β*	Organizational Support *p* - value
Self-leadership	.356	.000	.158	.000				
Perceived Organizational Support			.563	.000	-.551	.000		
Organizational Level	.113	.002	.195	.000	-.117	.000	.125	.001
Adjusted R^2		.140		.426		.331		.014
F Statistic		54.25		162.84		162.53		10.32
p - value		.000		.000		.000		.001

Discussion

This study revealed a number of significant differences between line and supervisory acquisition employees. Our analyses suggested that self-leadership was significantly related to creative potential and practiced creativity for both line and supervisory employees, with no significant differences in overall levels of self-leadership between the two groups. In contrast, we found significant differences between line and supervisory employees in creative potential, practiced creativity, gap scores and perceptions of organizational support for creativity. Specifically, line employees reported significantly lower levels of creative potential, practiced creativity and perceptions of organizational support for creativity, along with higher gap scores in comparison to supervisors.

Our analyses further suggested that although supervisors tend to have more creative potential than line employees, self-leadership appears to be the more important concept in

determining an individual's creative potential. Likewise, although self-leadership and organizational level are both important determinants of practiced creativity, employee perceptions of organizational support for creativity seem to be far more crucial. Similarly, perceived organizational support for creativity appears to be more important than organizational level in predicting creativity gaps in acquisition employees. In other words, employees who feel that the organization supports their creative efforts will be much more likely to practice creative behaviors, thus, lowering the gap between their potential and practiced creativity. Finally, organizational level was a significant determinant of perceptions of organizational support for creativity—with supervisory employees holding significantly more positive perceptions of support than line employees. In summation, our analyses suggest that self-leadership may be a key determinant of creative potential and practice among defense acquisition employees and that perceptions of organizational support for creativity, which tend to be weaker in non-supervisory employees, are critical in determining whether creative potential will be realized or whether a gap between potential and practice will result.

The results of this study have important theoretical, empirical and practical applications. This study adds to our understanding of the nature of the relationship between self-leadership, creativity and organizational support for creative practices at both the supervisory and non-supervisory levels. Our findings imply that self-leadership is a primary tool for facilitating creativity at all organizational levels and that active organizational support for creativity may be the key for reducing the gap between creative potential and practiced creativity that represents untapped creative resources. Our results also suggest that this gap is much more pronounced among line employees and that line employees generally perceive less organizational support for utilizing their creative resources than supervisors. In order to address this situation, an organizational intervention designed to increase self-leadership capabilities at all levels and to increase perceptions of organization support for creative practices among line employees in defense acquisitions would be well advised. More specifically, a structured self-leadership training program similar to those reported elsewhere in the literature (e.g., Neck & Manz, 1996; Stewart, Carson, & Cardy, 1996) could be conducted for acquisition employees. Such a training program could have the dual effect of increasing self-leading behaviors and, thus, creative potential while also strongly signaling organizational support for creative behaviors.

Although our findings suggest exciting avenues toward increasing self-leadership and unleashing creative resources at all organizational levels, our study is bound by certain limitations. First, the present sample was relatively homogeneous, consisting entirely of members of the Army Contracting Agency. As we have suggested, such a sample is especially appropriate for creativity research because the Department of Defense has taken a keen interest in tapping all creative resources available in order to sustain a competitive advantage. However, it is uncertain as to whether the results reported here would generalize to other samples of interest. Second, all items were self-reported and collected utilizing a single survey at a single point in time, thus raising concerns regarding measurement issues such as response set and social desirability biases. Given these potential problems, our findings should be viewed with some degree of caution. On the other hand, despite such inherent limitations, the use of self-reported items collected in a single administration is common practice in many aspects of social science research.

Future research should continue to examine the relationships between self-leadership, creative potential, practiced creativity, organizational level and organizational support for creativity. Specifically, future research should more closely examine the role of

organizational support as a moderator of the relationship between creative potential and practiced creativity and as a key mechanism for reducing the gap between these concepts in organizations. In addition, perceptions of support for creativity might be further subdivided from the organizational level to the work group and supervisory levels in order to provide additional insights (DiLiello & Houghton, 2006). Similarly, future research could continue to examine the differences between line and supervisory employees in terms of creativity and perceptions of support for creative practices, with an eye toward identifying ways to increase creativity at all organizational levels. In closing, our findings and suggestions have significant practical application in the context of the transformational efforts in the Department of Defense in support of warfighter readiness. An acquisition workforce of creative self-leaders could synergistically assist the organization in maximizing the utility of all organizational resources.

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Acquisition Community Team Dynamics: The Tuckman Model vs. the DAU Model

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Abstract

The Tuckman (1965) four-stage sequential model of team development (Forming, Storming, Norming, and Performing, or FSNP) represents today's most widely used model. However, the Tuckman model is a conceptual statement that was suggested by the data and has not been empirically validated (Tuckman, 1965). Hadyn, Teare, Scheuing and Armistead (1997, p. 118) state that, "despite increasing interest in teamwork, much of the literature on the subject is inconclusive and often derived from anecdote rather than primary research."

The goal of this research was to develop empirical evidence to determine whether or not the Tuckman model or some variant thereof provides an appropriate model to explain the development of small, short-duration technical teams within the Acquisition Community.

The results showed, to a 95% confidence level, that only about 2% of 321 teams studies followed the Tuckman model (FSNP). However a modified model, called the DAU Model (FNP—Tuckman model sans Storming), was experienced by 229 of the 321 teams (77%). This discrete three-stage model, along with a redefined Storming function that takes

place throughout the teams' duration, constitutes a strong model of team dynamics for the studied Acquisition population.

This research demonstrates that not only do technical teams generally follow the DAU model, but also that there is a strong correlation between teams producing above-average products and teams following this model. The results of this research strongly suggest the possibility that the productivity of a technical team may be significantly improved by guiding its development through a well-defined process.

Background

How to build effective teams is one of the most important management issues of the day. Significant effort is being expended to gain a better understanding of how highly successful teams develop in hopes that methodologies to enhance team productivity can be produced that will accelerate the movement of high-quality products to the marketplace (Osterman, 1994). In Quality Circles, Concurrent Engineering, and many other management innovations, the team is the organizational unit to which creative control is being delegated. As a result, there is a great need to better understand the development of technical teams.

The culture of many of today's businesses places as much emphasis on a person's ability to work together effectively in a team environment as on technical skills (Tarricone, 2002). Osterman (1994) found that teams are being used extensively by organizations that need to get products to market faster. Some industries have reported that teaming brings advantages such as increased productivity and decreased absenteeism (Beyerlein, 2001). According to Beyerlein, the use of task-oriented teams within organizations has spread across many industries, nonprofits, and national boundaries in the last decade. Kinlaw (1991) found that teamwork is the main driver for continuous improvement and increased competitiveness. According to Marks (2001), the advantage of teamwork is that people working together can often achieve something beyond the capabilities of individuals working alone. Furthermore, Marks points out that success is not only a function of team members' talents and the available resources but also of the processes team members use to interact with each other. Research on the development and functioning of teams is needed to enable organizations to retool human resource systems so that managers can better select, train, develop, and reward personnel for effective teamwork (Marks, 2001). To remain competitive, it is important for organizations to understand how to create and maintain teams that are highly effective in today's globally competitive environment (Yancey, 1998).

Introduction—the Importance of Teams to Defense Acquisition and the Defense Acquisition University (DAU) Connection

Short-duration, small technical teams represent a significant proportion of the team activities within the Department of Defense (DoD) acquisition community and corporate organizations. These teams come together, focus on the task at hand, produce whatever products are required, communicate their results, and then disband as easily and quickly as they were formed (Canadian Business, 2001). Wherever highly specialized knowledge spanning multiple disciplines is required, the technical team enjoys widespread use. Some examples are as follows:

- Multi-disciplinary Product Integration Teams

- Tiger Teams (narrow focus, single issue)
- Proposal Teams
- Design Teams
- Educational/Training Teams
- Problem Resolution Teams
- Product Development Teams
- Marketing/Sales Teams

In today's environment, short-duration, small technical teams drive an enormous quantity of critically important decisions within a broad range of organizations in all sectors of the US economy. The DoD acquisition community is one such sector that makes extensive use of technical teams. Thus, understanding how these teams develop is of critical importance to the DoD Acquisition Community.

DoD acquisition professionals are those in the government who are responsible for acquiring weapon systems for the Department of Defense. Their collective decisions, made primarily by technical teams, move hundreds of billions of dollars per year, influence the outcome of international conflicts, and determine the effectiveness of the US military. To perform its mission, the acquisition community employs thousands of technical teams to develop the information necessary to make critical decisions and to integrate the development and production of very large, costly, and complex weapon systems. The Integrated Product Teams (IPTs), which has been organic to both industry and DoD acquisition for many years, is a good example of a technical team. The IPT, along with all of the short-duration, small sub-teams it spawns is increasingly being hailed as the preferred way to manage large-scale acquisitions (Weinstock, 2002, p. 1). *DoD Directive 5000.1* requires that the, "Acquisition Community implement the concept of Integrated Product and Process Development (IPPD) utilizing IPTs as extensively as possible" (DAU, 2004, October 17, p. 113).

DoD technical teams are often multi-disciplinary and could include scientists and engineers as well as management, contracts, budget, security, quality, survivability, and logistics personnel from both the developer and the user organizations (DAU, 2004, October 17). DoD teams often include contractor personnel as well as government employees. DoD acquisition activity centers on extremely large and complex systems that often push the state-of-the-art in many fields simultaneously. The acquisition workforce numbers approximately 133,000 people, including both military and civilians. It is vital to the success of integrated military systems that all the stakeholders work together as efficiently and productively as possible (Weinstock, 2002, August 15).

Because countless lives, billions of dollars and the national interest are at stake, the US Congress required the Department of Defense to take action to promote high levels of professionalism and competency within its acquisition workforce. One action taken by the DoD was to establish a process of training and certification for individuals in the acquisition workforce. The Defense Acquisition University (DAU) was established to implement this training. This process, called the Acquisition Certification Program, was designed to ensure that an employee meets the professional standards (education, training and experience) established for acquisition career positions at three separate levels of decision-making responsibility; in addition, promotion opportunities are tied to these certification levels.

The DAU charter is to provide training to the DoD workforce that sets the direction for all DoD acquisitions. Due to the emphasis the DoD places on teamwork, many of the DAU classes are conducted utilizing student teams to generate typical DoD acquisition products. Examples of classes that make use of teams are: Systems Engineering, Program Management, Software Acquisition Management, and Information Technology Acquisition Management. The DAU's use of student teams is consistent with many conventional universities who are also requiring teaming activities in their courses. These student teams are used to enable the generation of more complex products and to prepare the students for the inevitable teaming requirement in the workforce. It was these DAU teams that were studied by this research.

The Tuckman Model

In 1965, Tuckman examined 50 empirical research efforts to arrive at his own group dynamics model. Tuckman (1965) concluded that groups develop through a sequence of four discrete stages: the first stage, Forming, is the initial group coming together; the second stage, Storming, involves conflict among the group members; the third stage, Norming, is when the group actually begins to find value in working together and establishes processes that enable the group to function; and the fourth stage, Performing, represents the time when the group is working together smoothly and is able to share ideas and accomplish goals. However, Tuckman (1965) warned researchers that the application of this model to generic team settings may be inappropriate since the majority of his data came from the population of therapy groups and human relations training groups. Note that the types of groups from which the Tuckman model was derived have almost nothing in common with the technical groups supporting DoD acquisition.

Many government organizations, contractors, and management consultants appear to be working under the assumption that a team's productivity can be significantly improved by optimally guiding the interaction of the team's members through the Tuckman model's sequence of stages (Glacel & Robert, 1995). Buchanan and Huczynski (1997) found the Tuckman model to be the preferred model of team development for all types of teams. It is widely believed in both industry and government that a leadership knowledgeable in how to apply Tuckman's theory of team dynamics can markedly enhance teaming performance. Top-tier consulting firms are teaching or offering training services based at least partially upon the assumption that the Tuckman model applies generically to most teaming arrangements (Glacel & Robert, 1995; Smith, 2005). Many DoD organizations have received such training. Glacel and Robert (1995) state that the Tuckman model can be used to facilitate any team-development process. They present the efficacy of the Tuckman model as a general model that applies to all teams. They state with certainty: "In the development of any team, certain stages of behavior [Tuckman stages model] take place which impact how well the individuals and the team accomplish their task" (Glacel & Robert, 1995, p. 97).

Notwithstanding its widespread use, Tuckman did not empirically validate his model (Tuckman, 1977). The government and industry managers are, thus, teaching and implementing a team-development model that has never be validated for any type of team, including the technical teams that are predominant within the DoD acquisition process. Large sums of money and critical outcomes may be influenced by the wide use of the Tuckman Theory, which was primarily developed through an analysis of data describing the development of therapy groups and human relations training groups during the mid-1960's.

Tuckman himself warned the group development community that his stage model had never been empirically validated and recommended caution in applying it to other settings (Tuckman, 1965). Subsequent to the original work, Tuckman and Jensen (1977) reviewed another 22 studies in an effort to determine if anyone had validated the Tuckman model. In 1977, the only new research that had attempted to validate the model was Runkel (1971). Runkel partially supported the Tuckman model; however, Tuckman and Jensen (1977) felt that the results were not necessarily reliable due to the researcher's methodology.

Even if the Tuckman model of group development was valid for therapy groups and human relations training groups, there is no reason to assume that it would be applicable to groups in other settings. Do the members of a missile design team interact in the same way as the members of a psychiatric therapy group? Perhaps, but independent empirical validation is needed before giving credibility to such an assumption.

Data Collection

The objective of this research was to establish and execute a methodology that would enable an objective, rigorous analysis of a large number of teams in order to determine whether these teams were following the four-stage Tuckman model, or some variant thereof. For this research, the team members were drawn from the population of students attending the DoD Defense Acquisition University (DAU) courses. The DAU employs technical acquisition teams in most of its classroom courses to emulate the activities that acquisition professionals face in their everyday work experiences. The classroom courses are used to provide hands-on experiential learning. Experiential learning at DAU requires that students work in teams in which they gain professional experience solving real-world problems that closely mirror both the teams and the tasks that they encounter in their workplace environment.

These DAU teams could technically be classified as academic teams because they take place in a classroom where an instructor assigns the team project. However, functionally it could be argued that they are more like work teams because the assigned tasks emulate real-world problems that the team members are typically asked to solve in a work-team environment within their own organizations. The DAU teams are brought together to learn and to practice working real-world problems. If the DAU team members are role playing, then the role they are playing is themselves at work.

As is the case with work teams, the researcher had no control over the team tasks. Individual team projects, which take from one to twenty hours of team interaction to complete, are relevant to the tasks team members accomplish within their own organizations. The team projects are selected by the course instructor. DAU teams normally contain 4 to 8 team members.

All team exercises within the DAU require products to be developed and delivered by the end of the exercise. The products delivered in the class are similar to products delivered in the DoD acquisition environment. For example, a Systems Engineering class is required to perform a Requirements Analysis Task within the class team. These are the people who perform Requirements Analysis Tasks within the Acquisition Workforce.

The instructor graded each team's product quality. It can be assumed that students are generally motivated to develop the best products they are capable of producing within

their teams because the quality of their work is openly graded. Furthermore, passing DAU courses is dependent upon the quality of their teamwork as well as the quality of their team products (in addition to their final exam grades). Since passing a DAU course earns a certain level of certification within the Acquisition Corps, and since certification levels are tied to career advancement opportunities (DoD, 2005, January 12), DAU students generally take their teaming activities seriously and are motivated to work well together.

For this research, the Diane Miller (1997) Group Process Questionnaire (GPQ) was utilized to collect data to determine if events defining the Tuckman stages took place within the DAU technical acquisition teams being observed. If the instrument determines that a team member observed “Tuckman events” taking place within the team, then data is gathered to define when these events occurred and how long they lasted. Dr. Miller involved team dynamics subject-matter experts to generate her GPQ and then performed a validation study to eliminate questions that did not reflect the team dynamics models of interest. The DAU Research Report entitled “Small, Short Duration Technical Team Dynamics” provides more details about how this instrument was selected (Knight, 2006). Miller’s questionnaire contains 15 questions that are reflective of the Tuckman model (Miller, 1997). Figure 1 provides a list of the 15 Tuckman questions included in the GPQ.

The GPQ required 10-20 minutes to complete. Each of the 15 Tuckman questions asks the individual to determine if an event (correlated with one of Tuckman’s four stages) happened during a specific teaming exercise and if so, when it happened and how long it lasted. The point at which the event occurred and its duration were recorded on a timeline scaled from 1-50. If the event was a singular event that occurred at one instant of time only, then the person would click a single unit (box) on the timeline. If it occurred various times with various durations, the person would indicate each occurrence and its duration by clicking a series of contiguous boxes. A sample timeline is shown in Figure 2.

Stage	Question	GPQ Question
F1	14	The team attempted to discover what was to be accomplished
F2	24	Individuals tried to determine what was to be accomplished
F3	31	The team tried to determine the parameters of the task
S1	1	There was conflict between group members
S2	5	Individuals demonstrated resistance towards the demands of the task
S3	16	The group was experiencing some friction
S4	20	Group members became hostile towards one another
N1	11	Individuals identified with the group
N2	23	Group norms were developed
N3	26	The team felt like it had become a functioning unit
N4	30	Group cohesion had developed
P1	3	Solutions were found which solved the problem
P2	6	A unified group approach was applied to the task
P3	21	Constructive attempts were made to resolve project issues
P4	22	Problem solving was a key concern

F=Forming S=Storming N=Norming P=Performing

Figure 1. Tuckman Questions in the Group Process Questionnaire

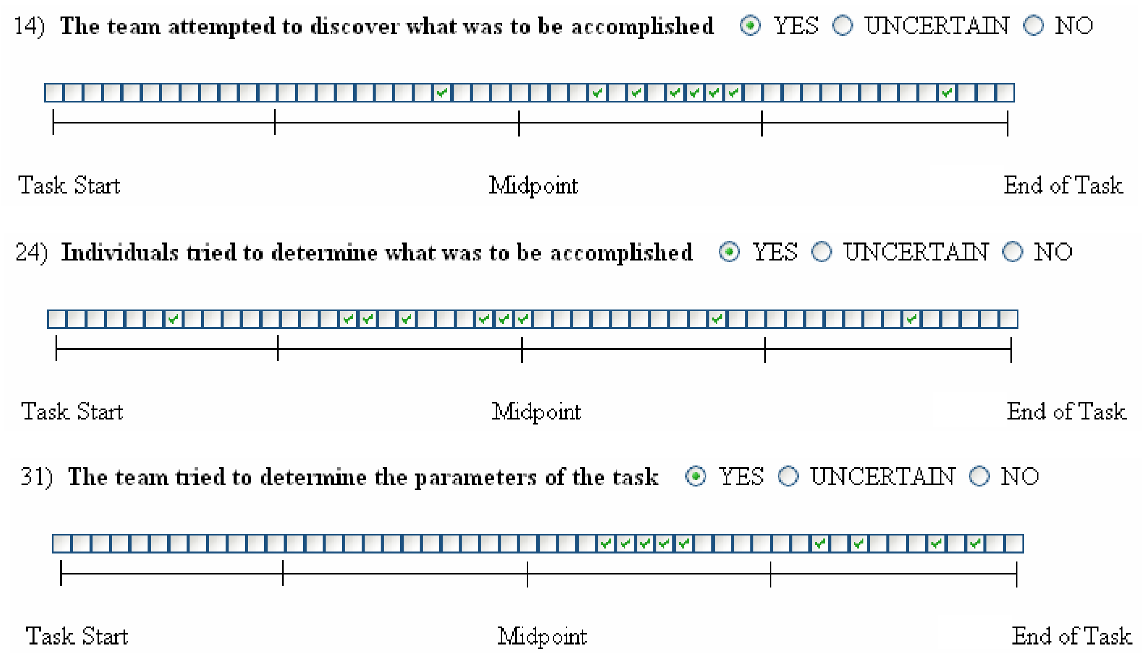

Figure 2. Sample Question Timeline

Originally, 368 teams were surveyed with a response rate of 90%. The research population consisted of 321 teams and 1448 individuals. The average team size was 4 to 5 members but ranged from 2 to 8 members. The durations of these team projects ranged from one hour to two-and–a-half days. This population contained 68% males, 30% females and 2% who did not indicate their gender. Because the more technical professions (particularly engineering) are predominately male, this lopsided gender breakdown is normal and expected within the DAU. The DAU students studied in this research project represent a typical set of DAU students. They are generally well-educated career professionals working in a predominately technical environment. Figure 3 shows the percent of team members versus highest degree attained. Note that 88% have at least a college degree (BS/BA) and almost 40% have completed graduate degrees. These team members are generally aware and bright and should have no trouble understanding the questions asked by the questionnaire or being able to relate those questions to the events they witness in their teams.

High School	BS/BA	MS/MBA	PhD Doctorate
12%	50%	36%	2%

Figure 3. DAU Survey Population Education Levels

The courses offered at DAU are typically not taken by inexperienced acquisition employees. These are not entry-level courses, but rather are aimed at midlevel and senior professionals who are actively trying to advance their careers. This group of career-ladder climbers tends to have more drive and energy and is a little more intellectually aggressive than the typical acquisition employee. The DAU teams in the research population are, on

the average, composed of midlevel (11-years experience) professionals on the way up in their organizations. They have been working in product-oriented technical teams in a professional capacity for over 7 years and have previously worked in teams with one or two of their current teammates. Incredibly enough, over 71% of them have had some training in the techniques of productive teaming. Bottom line: These teams are highly experienced, motivated, and well prepared to work efficiently together to produce whatever products are demanded by their various class exercises.

The DAU instructor evaluated the quality of each team's products. Figure 4 shows how those evaluations were distributed over the 321 teams. The instructors judged there to be 145 above-average, 151 average and 25 below-average products.

	Above Average	Average	Below Average
Number	145	151	25
Percent	45%	47%	8%

Figure 4. Instructor Evaluations of Team Products for 321 Teams

Analysis Methodology

This research defines a statistically valid teaming experience as one that can be proven to a 95% level of confidence to be derived from information measured by the GPQ that has been certified to be both accurate and statistically meaningful. That is, each team's qualitative and quantitative experience of a given sequence of Tuckman events (as measured by the GPQ) must be shown to be very unlikely ($P \leq 0.05$) to have occurred as a result of random fluctuations in the data (noise).

An assessment of the ability of the data collection methodology to fully support the goals of this research project was undertaken. A statistical analysis of the time-of-occurrence data generated independently by each DAU team member clearly demonstrated that the data is able to support statistically rigorous results and conclusions about whether or not DAU teams followed the Tuckman linear sequential model. Data-quality standards were enforced to ensure that the research database contained a minimum of noise and disinformation. Also, it was statistically shown that team members were able to clearly assess the behavior within their teams relative to the Tuckman model event descriptions described by the GPQ. Finally, it was shown that the time-of-occurrence data upon which the results of this research are based contain a high enough signal-to-noise ratio to ensure that derived results can be scientifically credible. Appendices N and M in the DAU research report derive the details supporting these conclusions (Knight, 2006).

To show that each team's experience of a given sequence of Tuckman events was very unlikely ($P \leq 0.05$) to have occurred as a result of random fluctuations in the data, an analysis of the sequences defined by the answers to the questionnaire was undertaken. This methodology is called Sequence Analysis. The GPQ contains 3 Forming questions, 4 Storming questions, 4 Norming questions, and 4 Performing questions. A sample showing one quarter of the sequence analysis algorithm is shown in Figure 5 below. Here we see the 3 Forming questions (F1, F2, and F3) being analyzed relative to the first Storming question (S1) and all of the Norming and Performing questions. The point is to determine the order in

which the four Tuckman stages (F, S, N, and P) occur as given by the timeline data associated with each question. The timing sequence defining the Tuckman model is F<S<N<P (the time when Forming occurs is earlier than the time when Storming occurs is earlier than the time when Norming occurs is earlier than the time when Performing occurs). Similarly, another three of these tables are used for Storming questions 2, 3 and 4. Possible responses are 1 if the sequence indicated by each cell is followed and a 0 if it is not. For example, in the data upon which this sample is based, the sequence F1<S1<N1<P1 did occur. Thus, a 1 is placed in the appropriate cell (second column, fourth row). Likewise, since our data did **not** support the sequence F2<S1<N1<P2, a zero is placed in the third column, fifth row. Each of these 4 tables could produce as many as 63 ones for a total of 252 total points if the Tuckman model is followed 100% of the time by that individual or team. These scores were then scaled to be between 0 if the Tuckman model is not followed at all and 100 if the Tuckman model is followed for all questions.

	F1 <	**F2 <**	**F3 <**
S1<	1	1	1
N1<	1	1	1
P1	**1**	1	1
P2	0	**0**	1
P3	1	1	1
P4	1	1	1
N2<	1	1	1
P1	1	1	1
P2	1	1	1
P3	1	1	1
P4	1	1	0
N3<	1	1	1
P1	1	1	1
P2	0	1	1
P3	1	1	1
P4	1	1	1
N4<	1	1	0
P1	1	0	1
P2	1	1	1
P3	1	1	1
P4	1	1	0
	19	19	18

Figure 5. One Quarter of Sequence Analysis Logical Algorithm (Tuckman Filter)

Another factor that must be considered to determine if the team is following the Tuckman model is how to combine individual data into team data. One approach would be to determine a team position on each Tuckman question and then run this team data through the Tuckman sequence-analysis model. The other approach is to run each individual's data through the Tuckman precedence model and then combine the Tuckman scores for individuals to come up with a team score. **The latter method was chosen for this research.** The reason for this choice is that the alternative requires good data to be

disregarded without good reason for doing so other than to simplify the calculations. If the first approach is selected, the minority opinion of the existence of an interpretative and subjective event is thrown out.

Once a Tuckman score is determined between 0-100, the significance of the score must be determined. A Monte Carlo simulation was used to generate a reference distribution of Tuckman scores. A large number (102,000) of questionnaires were filled out randomly—i.e., randomly answering “YES,” “NO” or “UNCERTAIN” to each of the 15 Tuckman questions and then producing random times-of-occurrence for each “YES” answer. A Tuckman score was calculated for each of the 102,000 random teams. A reference distribution was generated for these FSNP scores by sorting the 102,000 random FSNP scores into 100 bins. For example, all the FSNP scores between 15.5 and 16.499 were counted, and that number was put into bin 16. Because accuracy improves with the number of samples generated, the number of samples used (102,000) simply reflects the practical limits of the available computing resources.

Next, integrating over the distribution produced a cumulative probability curve. This probability curve was then used to generate a numerical level of confidence that a given score was not produced by random data. Obviously, very low FSNP scores requiring little specific organization of the input values are more easily produced by random inputs; yet, very high FSNP scores (requiring all F times to be less than all S times, etc.,) are nearly impossible to produce from 15 random inputs created by a random-number generator. Each FSNP score produced by the DAU data was required to be larger than the random FSNP score associated with a $_{SA}$ = 0.05 probability (of being produced by random processes) in order to be declared “significant.” In other words, for an FSNP score generated by a DAU team to be considered statistically significant, it must be large enough such that the probability of that score being produced by random input data is less than 0.05.

Additionally, a sequence of consecutive stages must be composed of discrete, clearly discernable, separate stages or it becomes a mixture of multiple stages—not a sequence of stages as required by the Tuckman model. If stage time-of-occurrences are so overlapped and intermingled in time such that one cannot clearly differentiate consecutive stages, then no bonafide sequence exists. To ensure this requirement for stage discreteness was met, I developed a stage-separation test that, when applied to the data representing the experience of a given team, would tell us (to some statistical level of confidence) whether or not that team’s experience, as measured by the GPQ, constitutes a valid sequence of Tuckman events. In other words, the conditions were precisely defined for sequence validation that determine when two broadly overlapping events belonging to consecutive stages can be said to be separated in time such that they represent two discrete and separate stages to some specified level of statistical confidence.

A parametric analysis was used to assess the sensitivity of research results to the analytical assumptions driving the analysis by varying the thresholds and criteria that numerically represented each assumption. User input parameters specifying constraints imposed upon the analysis were established as user inputs to the analysis engine to allow a parametric analysis of how each input affected both intermediate and final results.

To summarize: An individual’s or team’s FSNP score was counted as being supportive of the Tuckman model only if its value was equal to or greater than the calculated “significance threshold” and if the FSNP sequence was shown (to a 95% probability) to have discrete stages. The significance threshold is an FSNP score calculated within the

Sequence Analysis algorithm associated with a probability of 0.05 that a given FSNP score could have been generated by random inputs. From the random-reference distribution and its associated cumulative probability curve, it was determined that an FSNP score of 0.0976 had a probability of 0.05 of being random. Thus, any score equal to, or greater than, 0.0976 represented a significant score. More detail on random Tuckman score distributions and probability curves can be found in the DAU Research Report entitled "Small, Short Duration Technical Team Dynamics" (Knight, 2006).

In addition to determining if an individual and the team are following the Tuckman model at the 95% level of confidence, this research looked at what other possible forms of the Tuckman model were being followed (i.e., Forming, Norming, Performing OR Forming, Norming, Storming, Performing, etc.). There are 64 possible combinations of alternative sequences of the Tuckman stages. For each individual and for each team, a calculation was performed to determine which of these sequences was being followed. This was then plotted to determine which sequences showed up the most often. The two variants of the Tuckman sequential stages model that were most prevalent were F<N<P and F<N/P (Forming before Norming and Performing). These models were assessed using the same analytical methodology. In the exact same manner described above for creating a Sequence Analysis algorithm $SA_{F<S<N<P}$ that calculates FSNP scores in order to assess the degree to which a statistically valid Tuckman model (F<S<N<P) was experienced by DAU teams, an $SA_{F<N<P}$ algorithm was developed that calculates FNP scores in order to assess the degree to which a statistically valid F<N<P model was experienced by DAU teams. Similarly, an $SA_{F< N/P}$ algorithm was developed that calculates FN/P scores in order to assess the degree to which a statistically valid F<N/P model was experienced by DAU teams. The significance threshold for F<N<P sequences was 4.251, and the significance threshold for F<N/P sequences was 6.511.

Results

The final results are shown in Figure 6. Only 6 teams (2%) out of 321 experienced a statistically valid Tuckman sequence; it is clear that the technical acquisition teams of DAU did not follow the Tuckman model. This outcome was primarily driven by a lack of Storming within the teams. Secondly, Norming and Performing appear to be interspersed in time to such an extent that it is difficult to separate the two.

Tuckman Model - FSNP		
Test	**Teams**	**Individuals**
Raw Time-of-Occurrence	1%	3%
Sequence Analysis	2%	6%
Tuckman Variant - FNP		
Test	**Teams**	**Individuals**
Raw Time-of-Occurrence	49%	26%
Sequence Analysis	71%	44%

Tuckman Variant – F N/P		
Test	**Teams**	**Individuals**
Raw Time-of-Occurrence	71%	46%
Sequence Analysis	90%	70%

Figure 6. Results Summary

There were several attributes of the DAU teams that might possibly be related to the lack of Storming behavior. The first attribute is team size. Typical DAU team sizes were 4 to 8 team members. One might wonder if small teams Storm less than larger teams. Further research would have to be performed to provide a conclusive answer to this question; however, Benfield (2005) also found very little Storming in his data, yet his team sizes were not restricted to such small sizes. In fact, 43% of his teams had more than 11 team members. The second attribute is the short duration of teaming activity. The median DAU team duration was 4 hours, while no team duration was greater than 20 hours. The question here is: Do short-duration teams Storm less than longer-duration teams? To conclusively determine the effect of team duration upon the incidence of Storming, further research is required. However, according to Benfield's (2005) research, 53% of the teams he studied lasted longer than 12 months and also produced very little Storming behavior relative to the other stages.

The third attribute that may have influenced the lack of Storming within DAU teams is team setting. The DAU teams were in an academic setting which, because of the nature of DAU and DAU teams, could be considered somewhere between Tuckman's (1965) *natural* and *laboratory* settings; however, DAU teams are most similar to Tuckman's natural teams. Benfield (2005) studied *natural* teams working in a DoD technical environment and similarly found a low level of Storming relative to the other stages. There is yet another attribute of the DAU academic setting that may have influenced the amount of Storming behavior exhibited. DAU teaming exercises take place in the presence of an instructor and are subsequently graded by this instructor. This is analogous to a natural team when "management" is a part of the team or closely monitors the team. Cooperative professionalism is encouraged while conflict, resistance, and hostility are often discouraged whenever a neutral authority with significant power over the team members is observing the process. In other words, team members may have been exhibiting their best professional behavior rather than the less politically correct behavior they might have exhibited within a group of peers. Certainly, "resistance to the task" would be muted in the presence of the instructor who assigned the task and who was going to grade the task products.

In addition to the lack of Storming found, the distribution of Storming data was more or less uniform across the entire timeline (team duration), as shown in Figure 7.

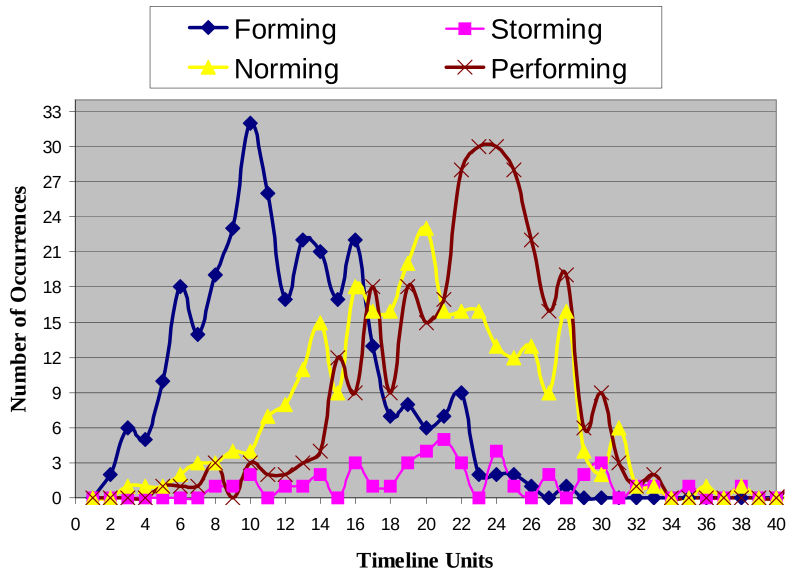

Figure 7. Average Time-of-occurrences for Each Stage for 321 Teams

This characteristic of a constant low level of Storming spread evenly across the entire duration of a team's activity was also observed in Benfield's (2005) data analyzing technical teams. The other three stages generally occurred at a specific location on the timeline, i.e., their distribution exhibited a well-formed peak on the timeline much like that predicted by LaCoursiere (1980). Thus, if the Storming questions were changed to be more sensitive to the vigorous (but cooperative, positive, and professional) competition of ideas that often takes place within a technical team, there may be more of this newly defined Storming (e.g., cooperative brainstorming) but perhaps still no well-defined Storming stage.

To achieve their goals, it is often necessary for technical team members to challenge each other. Although disagreements and divergent points of view were common among DAU teams, they usually were resolved quickly within a cooperative and non-confrontational (minimal friction, resistance, or hostility) atmosphere according to their technical merits. This type of professional challenging may have occurred at any time throughout the teaming process but did not cause many DAU teams to exhibit the Storming stage as defined by the Tuckman model and as represented by the Miller GPQ (i.e., conflict, resistance, hostility and friction). The two Storming questions that described conflict and friction (as in conflicting ideas, and the friction between competing viewpoints) were responsible for Storming behavior being lightly (14%) scattered throughout the DAU data. The Storming questions that focused on resistance to the task and especially the one focused on hostility between team members were not relevant to the observations of the teams being studied.

In summary, a comparison to Benfield's (2005) data suggests that the lack of Storming within the DAU data is not an attribute of team size, duration, or team setting. Thus, it is suspected that the lack of Storming is a natural attribute of technical professionals working under time constraints to produce good-quality products for which they are held collectively responsible. The technical team setting of this research and Benfield's (2005) research is dramatically different in form, purpose and content than the dominant setting (therapy groups) used by Tuckman (1965). It seems reasonable that Storming, as Tuckman

(1965) defined it and Miller (1997) implemented, would occur more often in a therapy group setting emphasizing **personal** interaction than in a technical team setting emphasizing **professional** interaction where each team member's personal success is dependent upon the collective success of the team.

Performing Sequences Analysis for the F<N<P three-stage (=0.05) model revealed that 229 (71%) of the 321 teams generated statistically valid sequences that followed the F<N<P three-stage model. Of these, 161 (50 %) teams also produced an F<N<P average time-of-occurrence sequence of stages. Also, 637 (44%) of the 1,448 individuals experienced a statistically valid F<N<P sequence. This variant does clearly constitute a majority model of team behavior. Because almost 3/4 of the DAU teams experienced a statistically valid F<N<P sequence, the F<N<P model is a reasonably strong contender for a general model of technical acquisition team dynamics. I refer to the F<N<P model as the DAU model.

Certainly, more research is required to evaluate the causal connection between a team's productivity and its experience of the F<N<P development process. More work will be needed to assess the efficacy and general applicability of guiding a team through the F<N<P development process in order to enhance its performance. If the definition and description of Storming is generalized in the survey instrument to include brain storming, perhaps it too would play a part in developing a strategy to optimize team performance.

Because the Norming and Performing behaviors seemed to be intermingled on the timeline (on the average, their means are separated by about 2.5 timeline units), differentiating between the first (F<N<P) and second (F<P<N) most commonly experienced sequence is problematical. Consequently, a two-stage model F<N/P (Forming occurs before Norming, and Forming occurs before Performing) that combines both should represent the single most widely experienced sequence. The Sequence Analysis (=0.05) was applied to the two-stage model F<N/P. The results indicate that 290 (90.34 %) of the 321 teams had a statistically valid experience of the F<N/P sequence. This variant clearly constitutes a strong model of DAU team behavior. In addition, 895 (62%) of the 1448 individuals also experienced a valid F<N/P sequence. Unfortunately, a simple two-stage model (first a team experiences Forming, and then it experiences everything else) does not provide much information about how one might possibly optimize team productivity other than make sure that every team thoroughly accomplishes Forming at its beginning.

Figure 8 shows that for all three sequence models, above-average teams produced the most statistically significant results followed by average teams, while below-average teams produced the fewest statistically significant results. The data shows consistent descending stair-stepped results in quantity of sequences generated for each team dynamics model as the teams' rating moves from above average to below average.

Sequence	Rating	Number	Percent
F<S<N<P	Above Average (145)	6	4.14%
	Average (151)	0	0
	Below Average (25)	0	0
F<N<P	Above Average (145)	114	78.62%
	Average (151)	102	67.55%

	Below Average (25)	13	52%
F<N/P	Above Average (145)	138	95.17%
	Average (151)	131	86.75%
	Below Average (25)	21	84%
Sequence	**F<S<N<P**	**F<N<P**	**F<N/P**
Correlation	**0.95**	**0.99**	**0.95**

Figure 8. Instructor Evaluation vs. Teams Producing Statistically Significant Sequences

A chi square r x c contingency test was performed to determine the correlation between instructor assessment and a team's probability of producing one of the three sequences of Tuckman stages (F<S<N<P, F<N<P or F<N/P). The correlation numbers given in Figure 8 are the probabilities that the populations are not independent—i.e., the probability that there is a relationship between a team's performance and the model of team dynamics followed by that team. Correlations of 0.95 or greater are considered to represent a relationship between populations that is statistically significant. The more productive and successful a team was, the more likely they were to observe one of the three sequences of Tuckman stages assessed by this research.

After generating a distribution of stage time-of-occurrence data, it was noticed that the stage times-of-occurrence for all 321 teams tended to group together. In other words, all the DAU teams, regardless of their task or duration, experienced the Forming, Norming, and Performing stages at about the same place on the 50-unit timeline. To verify this phenomenon, the Kruskal-Wallis test, as described by Conover (1999) was used to determine if an ensemble of the DAU time-of-occurrence data generated by each of the 1448 individuals for each Tuckman question could be separated into discrete stages. The data indicate that an ensemble of all DAU team members from all teams do collectively experience a discrete sequence of at least three Tuckman stages. This result corroborates the possibility of a universal experience of the Forming, Norming, and Performing stages of the Tuckman model (Tuckman variant 1, F<N<P, DAU Model) at a somewhat predictable fraction of a team's duration. However, the Storming data was spread across the entire timeline, producing no distinct peak. Forming appears to occur at about 25% of the timeline, Norming at about 40% of the timeline, and Performing at about 45% of the timeline.

Primary Conclusions

The development of technical acquisition teams appear to follow a variant of the Tuckman model (F<S<N<P). This model, which I will call the DAU Team Dynamics model, has three discrete stages (F<N<P) and one continuous brainstorming stage that takes place over the entire duration of the team effort. The brainstorming activity can be described as group members challenging each others' ideas and approaches in a cooperative way with the intention of producing a better product or improving the team's process (efficiency and productivity).

This research demonstrates that not only do technical teams follow the DAU model, but that teams following the DAU model produce better products than teams that do not follow this model. It may, therefore, be possible to significantly improve productivity in

technical teams by facilitating the DAU model—that is, to encourage teams to first coalesce as a team and form their intent and structure, then develop their approach, ground rules, and processes, to be followed by assigning tasks and getting the work done—all the while cooperatively challenging, re-evaluating, and improving the overall team process as they work together to accomplish the task they were given. Additionally, one should expect the Forming stage of the DAU model to occur at about 25% of the timeline, the Norming stage to occur at about 40% of the timeline, and the Performing stage to occur at about 45% of the timeline. Establishing a firm causality between following the development structure of the DAU model and improving a technical team's productivity will require additional corroborating research.

Secondary Conclusions

The tools and methods developed in this research project are widely applicable to a broad assortment of team-dynamics research projects. Furthermore, developing a custom set of tools to fit each individual research application is not difficult. These two facts should encourage much additional research.

Though learning how to make teaming more efficient and productive has always been considered of vital importance to large numbers of users, the research process has been so cumbersome, difficult, inconsistent, and lengthy, that the field has languished (relative to its importance) for decades. Now that this research project has developed a statistically and scientifically rigorous process that enables the assessment of a large number of teams relatively easily and quickly, it is hoped that the pace of progress will accelerate. The analysis engine and methodology developed for this project provides a general model for facilitating low-budget, quick turn-around, high-yield, and statistically rigorous research focusing on various team types, settings, sizes, durations, compositions, and configurations. Fortunately, an instrument and its associated analysis engine once developed can easily be used by others to perform similar research in different settings, with different populations, with different types of tasks, and with teams of different sizes and durations.

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The Relationships between Work Team Strategic Intent and Work Team Performance

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Abstract

Overview

Teams can be a significant resource to business leaders and can help lead to greater program successes. Little empirical data exist on what strategic characteristics make teams more effective. This study was conducted on 57 student project teams in 12 classes (327 respondents) in a Defense Acquisition University (DAU) executive level, six-week program management class in six different locations. The study not only underscores the significance of team focus on performance but also highlights how team characteristics affect team focus and performance. The results of this study have applications to the successful use of project teams throughout the DoD and in the commercial industrial workplace.

Results

Significant direct relationships were found in the 15 tested hypotheses between work team strategic intent and team performance as measured by team self-assessments and instructor assessments. There was also found to be a relationship between the team self-assessment of performance and the instructors' assessment of the team performance.

This study provided empirical evidence on the significant relationships between work team strategic intent and work team performance. The research accomplished the following:

1. Provided empirical data on the positive correlation relationships between work team strategic intent and work team performance.

2. Defined characteristics that were used to determine the strategic intent of a work team or any work unit.

3. Created a survey to measure strategic intent of team members and teams in general.

4. Introduced the study of strategic thinking or use of strategic intent as a method for evaluating team performance.

Introduction

Organizations operating in today's complex, changing and sometimes chaotic work environments, both in the government and commercial industries, appear to be more and more dependent on using work teams to leverage themselves to be more creative, efficient, and focused. Warren Bennis (1985), in his book *Leaders, The Strategies for Taking Charge,* describes the need for cooperation, communication, and collaboration between individuals in order to achieve greatness—and emphasizes the successful deployment of teams in the last two decades to achieve these same results.

In today's society, as complex and technologically sophisticated as it is, the most pressing projects require the committed, coordinated, and connected contributions of many talented people. Gone is the myth of the Lone Ranger who can work alone and is larger-than-life. Tomorrow's competitive organizations will be managed and inspired by teams of experts, skilled technicians, and team-appointed leaders. Projects, work efforts, and entire programs will be accomplished by a network of linked, disciplined workers skilled in their own right but connected by their commitment to their team's greater cause, goals, and/or objectives (Bennis & Biederman, 1997).

In the classic written about teams, *The Wisdom of Teams*, authors Jon R. Katzenbach and Nicholas K. Smith identify numerous teams in various industries (Citibank, General Electric, Hewlett-Packard, etc.) that have been continually successful in employing high-performing, self-managed work teams (2003). They state that a real team that is appropriately focused and rigorously disciplined is the most versatile unit an organization has for meeting both performance and change challenges in today's complex global markets.

The use of teams has been increasing for the last 20 years. In recent data collected from *Fortune* 1000 companies, it was highlighted that the use of self-managed teams has increased from 28% in 1987 to 68% in 2003 (Lawler, Mohrman & Ledford, 1995). A study of related research on "self-managed team" underscored the fact that nearly every major American corporation is considering adopting self-managed team as an organizational design somewhere in their organization (Manz & Sims, 1993; Wellins, Byham & Wilson, 1991).

In addition, a GAO study in April 2001 highlighted the specific advantages of using Integrated Product Teams (IPT) as a "best practice" to improve how the Department of Defense develops and acquires weapon systems (2001, April 10). The report identifies specifically the successful use of IPTs by the military in the Advanced Amphibious Assault Vehicle Program (AAAV) to reduce the time needed to reduce a system design decision

from 6 months to about a week. It also highlighted three commercial companies that effectively used high-performing, self-managed teams to improve their product development capabilities. Those were: Daimler Chrysler, Hewlett-Packard, and 3M.

Organizational changes are occurring with ever-increasing frequency, and the scope of change is often revolutionary. Effective strategic management can help deal with this turbulence and, in many cases, has become a key factor for organizational success. Organizations must be flexible and able to respond to these environmental challenges with their strategic processes, implementation procedures, and organizational structure.

An important aspect of strategic management implementation is how this critical information and way of doing business is being infused into the operational end of the business. Strategic management implementation is extremely challenging; lasting implementation is usually the exception, not the rule, due to the resistance to this change of doing business and the many layers of the organization that must be touched with this enhanced way of doing business.

An effective method to implement strategic management is through work teams that are focused or intent with the same strategic goals and missions of the corporate leadership. Teams with a significant level of the same strategic focus on the purpose, objectives, and execution strategies that are aligned with the corporate goals and missions can be an extremely effective implementation tool for the organization. This applies in a similar nature to a student work team in the classroom, attempting to learn new skills and knowledge.

It was hypothesized in this study that if student team members are aligned in their purpose and objectives to the course goals and learning objectives, then higher levels of student team performance or learning will result that is aligned more directly with the course's and the instructors' learning objectives. The team's understanding of and commitment to the course's purpose, objectives, and strategies may help ensure that the team is effectively achieving the reason for being in the course, learning and performing the course's goals and objectives. An objective may be to ensure that the students are aligned to the same strategic focus or intent as the instructors' and course managers' goals of achieving the overall course objectives.

Business and education leaders have been faced with an increasingly changing environment, which increases the need for effective and focused strategic planning and implementation practices. The speed and volume of transformation have increased dramatically in the last century, and this trend is expected to continue at an even greater speed and impact in the 21st century. Speed and change are expected to continue, and with this challenge, more innovative and effective strategic/future-oriented measures must be achieved by business and education leaders to ensure they are able to sustain their operations and maintain the proper strategic focus and intentions. The increased level of change and the need to apply effective structural change initiatives, such as teams, to this environment of change prompted the interest in this study.

This research study obtained empirical data from classroom surveys administered to student work team members attending a 6-week Program Managers' PMT 352B course at Defense Acquisition University (DAU) and to DAU PMT 352B faculty members during a year's period of time (July 2005 to July 2006). The data from the surveys determined each respective student team's Strategic Intent and each team's Self-assessed Team Performance and Instructor-assessed Team Performance. Pearson's *r* correlation

coefficient and Spearman's *rho* ranked-order correlation tests were used to determine the relationship between team Strategic Intent variables and Team Performance—both team self-assessed and instructor-assessed. This paper presents a summary of the reasons for the study and the results of the study which established empirical data to support the general hypothesis that increases in work team strategic intent or focus will cause increases in the work team's performance.

Past research has provided some general discussions and initial studies on the relationship between team characteristics such as Strategic Intent and Team Performance. Previous research has also identified the need for further research, and empirical data were needed in this area of research to determine and measure the relationships between the variables of team strategic thinking (Strategic Intent) and Team Performance (Athanassiou, Crittenden & Kelly, 2000; Bartlett & Ghoshal, 1998; Hamel & Prahaland, 1994; Thompson & Strickland, 1996; Tregoe & Zimmerman, 1989).

Katzenbach and Smith (2003) have accomplished extensive work in the study of teams and their effectiveness. They admitted that no empirical data exist to prove their theories on team effectiveness. This research study provides data to support Katzenbach and Smith's study (2003) and theories on teams: teams can more effective or perform better if they maintain a Strategic Intent or focus that was understood and committed to by all the team members. This paper highlights the purpose of the study, the key concepts studied, the research questions and hypotheses, the results and, finally, some conclusions reached from the study.

Purpose of Study

The purpose of this study was to use survey data from student work teams and instructors' surveys to examine the relationship between work team Strategic Intent (strategic purpose, objectives, and strategies) and work team Performance. The studied work teams were chosen from student work teams attending Defense Acquisition University (DAU) PMT 352B course. PMT 352B is a 6-week-long course which teaches the concepts and skills of being successful program managers. It simulates the conditions and stresses that senior DoD managers are normally presented with in making daily and long-term strategic program management decisions. Team Performance was assessed by surveys administered to the work teams (self-assessment performance) and to the PMT 352B instructors who were teaching the student work teams (external, instructor assessment).

The specific strategic elements studied included the teams' strategic purpose, objectives, and strategies that had been determined in previous academic and business research (Ackoff, 1974; Ansoff & McDonnell, 1990; Anthanassiou et al., 2000a, 2000b; Elrod, 1999; Hackman & Wageman, 2005; Kraft, 1996; Schein, 1980; Thompson, 1993), related to the decision-making success of an organization and having an effect on organizational performance and long-term successes.

Strategic thinking and alignment of this thinking have been used in past research to measure a team's ability to agree among the members on strategic goals, objectives, and strategies that focus on or align the team's efforts on shared performance objectives (Anthanassiou et al., 2000a). This alignment or cohesiveness in strategic thinking in the Anthanassiou et al. studies (2000a, 2000b) was measured to determine the difference or variance between the leader's and the team's perceptions and commitments to the same strategic elements (team goals, objectives, and strategy). They were studied to determine

the effects on performance. In most cases, the higher the alignment or congruence in strategic thinking, the better the performance of the team and its associated business outcomes (financial and social).

This research study acquired empirical data from student work team members attending classes in PMT 352B. The strategic characteristics of specific PMT 352B student work teams were calculated from information gathered from team surveys. These students were mature (generally 35 to 60 years of age) Department of Defense (DoD) students attending this technical training course on program management with Defense Acquisition University. The teams' understanding of and commitment to their respective team's strategic management characteristics was measured by surveys administered to the teams in their location of work (the classroom) by the researcher and trained faculty members. The surveys obtained each team member's perceptions of his understanding of and commitment to the specific team strategic elements studied in this research—team purpose, objectives, and strategies. These strategic elements helped define the teams' strategic characteristics and were defined in the team survey, so there was an understanding of these variables by the survey respondents. This helped define what were the strategic elements being studied and what were the data the researcher was seeking.

Data were collected from each team member on his perception of how similar or linked was his understanding of and commitment to the team compared to the other members of the team's understanding of and commitment to the team's purpose, objectives, and strategies. Team similarity was measured both in terms of understanding and commitment to these strategic elements.

The research calculated team data on team similarity of team strategic characteristics as measured by understanding and commitment to team purpose, objectives, and strategies. The research analyzed the relationship of these strategic characteristics (similar understanding of and commitment to team purpose, objectives, and strategies) to Team Performance—measured by the team's self-assessment of its performance and by an external assessment by the team's instructor(s). The study then analyzed the relationship or similarity between a team's self-assessment of its performance and the instructors' external assessment of the same team's performance. The researcher theorized that the similarity or alignment of a team's purpose, objectives, and strategies was a strong predictor (a direct correlation) of how well the team members worked together and effectively communicated in making critical choices vital to the successful performance of the team. Team effectiveness in making decisions and accomplishing the course objectives was theorized to be related to the congruence or alignment of each team member's individual similarity perceptions of his strategic characteristics to the other members on the team.

This congruence was measured in terms of the member's understanding of and commitment to the other team members' strategic elements of purpose, objectives, and strategies. How congruent or similar the members' strategic characteristics were, the more effective the team should be in accomplishing its purpose, objectives, and strategies. Accomplishing these team strategic elements would make the team perform better, both as determined by the team's own standards and by the instructors' criteria of learning the course objectives. The following research model in Figure 1 helped to identify the variables (independent and dependent), research questions, hypotheses, and relationships involved in this research study. The next two sections highlight the two key variables studied: Strategic Intent and Team Performance.

Strategic Intent

The research model in Figure 1 highlights the key variables and relationships studied in this research. The Strategic Intent of the team is defined and highlighted in the figure as consisting of three team strategic elements: purpose, objectives, and strategies. Strategic Intent is further defined as to how each team member was focused or had similarly aligned understanding of and commitment to the team's strategic elements (purpose, objectives, and strategies), as measured by surveying each team member. The actual measurement of Strategic Intent was then computed by measuring the overall average team scores for Strategic Intent from the individual members' scores on the team survey.

One of the basic reasons for using the term "Strategic Intent" to highlight the strategic thinking or focus of the teams in this study was to use the previous work of Hamel and Prahaland (1989) in this conceptual or research area. Strategic Intent captures the meaning and nature of the characteristics most representative of what exists in teams or other groups that highlight what they think and perceive about their future goals, vision, or purpose. As discussed by Hamel and Prahaland, an organization's Strategic Intent or focus is part of the "dream that energizes a company and is more sophisticated and more positive than a simple war cry" (p. 64). These two authors highlighted that Strategic Intent implies a sense of organizational direction, discovery, and destiny. They explained that Strategic Intent is more than the implied particular point of view about the long-term market or competitive position that an organization hopes to build over the coming decade or so. It is the stated and vital focus that makes an organization competitive and driven toward a vision, a future direction, or a destiny that consumes its nature and reason for being (Hamel & Prahaland, 1989). These are the characteristics most representative of what this research desired to study and why the research was originally conducted.

This research study embraced a similar meaning and value to team Strategic Intent developed by Hamel and Prahaland—the committed and understood strategic elements of the team that united or focused team actions and decisions as measured by the team's commitment to and understanding of the team's purpose, objectives, and strategies.

In this research, teams were considered important to facilitating strategy implementation and integration when properly focused on the organization's strategic purpose, objectives, and strategies. The strategic focus or intent of teams was studied to determine what relationship strategic intent has on overall Team Performance. Studying this relationship in teams could have a direct bearing on how these same variables (Strategic Intent and Performance) are related in larger organizations, such as divisions, business units, plants, and firms.

Adequate controls of the decision-making processes are in place within the focused team, which facilitate it to be more effective and successful as a decision-maker in focusing on the team purpose and objectives. Additionally, it can also make the team more integrated and focused within the overall organizational structure, enabling or leveraging the organization itself to be higher performing in the long term. Properly disciplined, focused, and integrated teams are the ones that become high-performing teams, and they have been considered "the most versatile unit organizations have for meeting both performance and challenges in today's complex world" (Katzenbach & Smith, 2003, p. xiii).

In their book, *Built to Last*: *Successful Habits of Visionary Companies*, Jim Collins and Jerry Porras (1994) described the strategic elements or intent needed to ensure that

effective strategic decisions can be made. In their study of 18 highly successful visionary companies, Collins and Porras highlighted that core ideologies are relevant to making effective strategic choices. It's what "drives" these companies to conform to be successful in developing new products and services. This same emphasis on Strategic Intent was previously highlighted by Ansoff and McDonnell (1990) and Mintzberg (1994).

The premise of Collins and Porras' 1994 book is that core ideology or Strategic Intent provides the foundation for the continual successes of the 18 visionary companies, the performance of which the researchers tracked over a 6-year period. These companies were standouts in their industry, and Collins and Porras theorized that the reasons for their continual successes were directly related to the existence of a core ideology upon which the firms and their upper-echelon management teams based their existence and strategic behavior. Their book concludes that if the core ideology of a firm and its strategic thinking are properly aligned with the environment, the firm and its thinking will have a greater opportunity to be successful in the long term, and it will bring in above-average performance returns and profits.

The work conducted by Collins and Porras is noteworthy and highlighted the usefulness of Strategic Intent or core ideologies in determining successful performance. Their premise is that based on their study and thinking of core ideologies, firms are able to sustain their outstanding performance in the competitive market by staying focused on their core ideologies. Their study, although popular with business leaders, is limited in the empirical sense since no hard data exist in their studies that prove or empirically support their theories. They have significant anecdotal information and cases but not empirical data. As discussed, the purpose of this study was to help identify and collect empirical data on the effects of Strategic Intent on performance.

Team Performance

The concept of Team Performance and how to measure it is critically important to the successful deployment of teams in any environment (Kraft, 1996). There is the general belief that teams make organizations more effective. However, few research efforts have measured team effectiveness with empirical data. The research cited in this study focused primarily on the manufacturing teams that can be assessed using operational measures such as productivity, efficiency, delivery time, defects, and scrap (Beyerlein, 1995). Some of the challenges presented in this research study on measuring Team Performance were similar to many studies that relied upon self-reported assessments, especially when measuring Team Performance. Team Performance has been studied extensively, and many techniques exist to measure it. How to measure Team Performance in the classroom or even in a program office environment is a challenge without using self-reported or self-assessed performance measures or data.

Podsakoff and Organ's (1986) work highlighted that the most critical concern was that the use of self-reports was identifying the potential causes of "artifactual covariance" between self-report measures of what were presumed to be two distinctly different variables. They stressed that when the same persons provided the researcher with self-report measures of two or more different constructs, what could account for any correlations that were found in the research could be a result of the "artifactual covariance" and bias in the respondents' self-reported data and not the natural correlation between the variables. In other words, false correlations would be assumed in the research, based on the nature ("artifactual covariance") of the self-reported data and not on the actual relationship

occurring in the cases analyzed. The authors highlighted several techniques to reduce the effects of this overlapping influence of the respondents' self-reported data. All of these methods were highlighted as a means to reduce the effects of obtaining data from self-reports.

The Podsakoff and Organ (1986) article highlighted, though, that under specific conditions it seems that self-report data in organizational studies are "here to stay." They also reported on another study by Howard, Maxwell, Weiner, Boynton and Rooney . (1980), which noted that under many circumstances, self-reports might represent more accurate estimates of population parameters than behavioral measures. Podsakoff and Organ also stressed in their study that it is unlikely that such techniques of using self-reports will be abandoned. They do recommend that caution be taken to ensure that the right conditions exist to minimize the effects of self-reported data on the correlations and conclusions made concerning the data relationships. Gupta and Behr (1982) emphasized that despite the problems in the use of self-report measures in organizational research, the practical utility of self-reported data makes them a necessity to organizational behavior studies. Self-report data are extremely useful and make them "virtually indispensable in many research contexts" (Podsakoff & Organ, 1986, p. 540).

In the context of this research, the application and usefulness of self-reported data from team members attending PMT 352B courses are justified, based on the fact that the self-reported data are collected at different locations/settings, at different times, and using consistent but varying instructors in gathering the data and that the data are aggregated at the team level (one level above the team-member level, where the data were originally gathered). These are all methods, as explained by Podsakoff and Organ (1986), which reduce the negative effects of self-reported data.

The nature of the data used in this research also necessitated that to obtain team characteristics on Strategic Intent, the natural source of the information would be from the team members. The team members were the most reliable source of information on how they thought about the Team Performance and how similar they perceived their beliefs to be regarding team purpose, objectives, and strategies (Strategic Intent). It would be difficult, if not impossible, to obtain "true" unbiased, objective data on teams' perceptions of their strategic thinking and their performance without using self-reported data.

The effects of self-reported data have been assessed in this research. It was determined that given the nature of the self-reported team member data (aggregated at team level, collected from different sources, locations, and times), the effects of "artifactual covariance," as highlighted by Podsakoff and Organ (1986), were minimized in this research.

It is evident that the problems of measuring Team Performance are very complex and difficult to pinpoint. The existing performance measurement systems in place in an organization are usually not aligned with new initiatives or changes, such as team development, occurring in today's workplace. In most of these cases, the measurement systems do not adequately reflect the impact on efficiency and effectiveness of the latest initiatives (Beyerlein, 1995). Because of these many difficulties with the lack of integrated performance-measurement systems and the complexities of how teams affect organizations, it is difficult, if not impossible, to effectively measure the value of teams with existing databases or performance-management systems. Therefore, it is believed that the only

effective way to measure Team Performance is through self-assessment of Team Performance. Lets know understand the study's research questions and hypotheses.

Research Questions and Hypotheses

This study was concerned with a general broad research question that focused on determining the relationship between work team Strategic Intent and Team Performance. The purpose of the study was to complete a thorough, descriptive, correlational relationship study on the six team Strategic Intent variables dealing with the teams' strategic thinking and on the performance of the teams as assessed by the team members themselves and by the teams' instructors in PMT 352B program management courses.

The research study gathered empirical evidence to answer these research questions and provided data to support these hypotheses:

RQ1. What was the relationship between the overall Team's Strategic Intent and the overall Team's Performance (team member self-assessment)?

Ha1. There was a statistically significant relationship between the overall Team's Strategic Intent (Independent variable/interval data) and the overall Team's Performance (team member self-assessment) (Dependent variable/interval data). The statistical test used was the Pearson's *r* correlation coefficient.

RQ2. What was the relationship between the Team's Strategic Intent as measured by the two variables a-b below and Team Performance (team member self-assessment)?

a. Understanding of Team Purpose

b. Commitment to Team Purpose

Ha2. There was a statistically significant relationship between the Team's Strategic Intent as measured by the two variables (Independent variable/interval data) a-b below and Team Performance (team member self-assessment) (Dependent variable/interval data). The statistical test used was the Pearson's r correlation coefficient.

a. Understanding of Team Purpose

b. Commitment to Team Purpose

RQ3. What was the relationship between the Team's Strategic Intent as measured by the two variables a-b below and Team Performance (team member self-assessment)?

a. Understanding of Team Objectives

b. Commitment to Team Objectives

Ha3. There was a statistically significant relationship between the Team's Strategic Intent as measured by the two variables (Independent variable/interval data)

a-b below and Team Performance (team member self-assessment) (Dependent variable/ interval data). The statistical test used was the Pearson's r correlation coefficient.

a. Understanding of Team Objectives

b. Commitment to Team Objectives

RQ4. What was the relationship between the Team's Strategic Intent as measured by the two variables a-b below and Team Performance (team member self-assessment)?

a. Understanding of Team Strategies

b. Commitment to Team Strategies

Ha4. There was a statistically significant relationship between the Team's Strategic Intent as measured by the two variables (Independent variable/ interval data) a-b below and Team Performance (team member self-assessment) (Dependent variable/interval data). The statistical test used was the Pearson's r.

a. Understanding of Team Strategies

b. Commitment to Team Strategies

RQ5. What was the relationship between the overall Team's Strategic Intent and the overall Team's Performance (external instructor assessment)?

Ha5. There was a statistically significant relationship between the overall Team's Strategic Intent (Independent variable/interval data) and the overall Team's Performance (external instructor assessment) (Dependent variable/interval data). The statistical test used was the Pearson's r.

RQ6. What was the relationship between the Team's Strategic Intent as measured by the six variables a-f below and Team Performance (external instructor assessment)?

a. Understanding of Team Purpose

b. Commitment to Team Purpose

c. Understanding of Team Objectives

d. Commitment to Team Objectives

e. Understanding of Team Strategies

f. Commitment to Team Strategies

Ha6. There was a statistically significant relationship between the Team's Strategic Intent as measured by the six variables (Independent variable/interval data) a-

f below and Team Performance (external instructor assessment) (Dependent variable/ interval data). The statistical test used was the Pearson's r Correlation Coefficient.

a. Understanding of Team Purpose

b. Commitment to Team Purpose

c. Understanding of Team Objectives

d. Commitment to Team Objectives

e. Understanding of Team Strategies

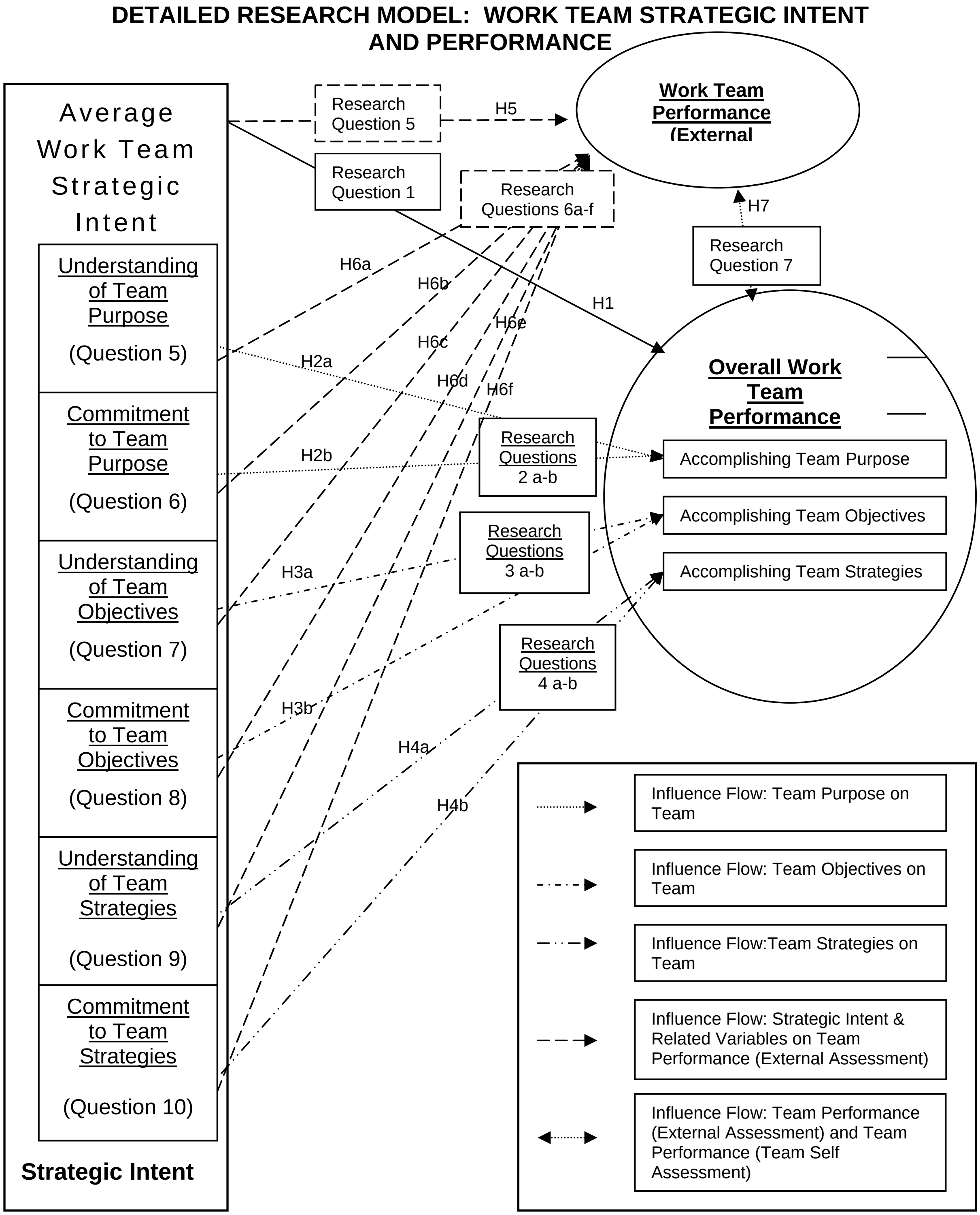
f. Commitment to Team Strategies

RQ7. What was the relationship between the overall Team's Performance (self-assessment from team survey) and the overall Team's Performance (Instructor assessment from instructor survey)?

Ha7. There was a statistically significant relationship between the overall Team's Performance (self-assessment from team survey) and the overall Team's Performance (instructor assessment from instructor survey). The statistical test used was the Pearson's r correlation coefficient.

The following figure highlights the relationships, research questions and hypotheses of the study.

Figure 1. Research Model with Hypotheses



Instrumentation

There were two surveys involved in the data accumulation. The first survey was the team survey. The second survey was the instructor survey. A team-member survey questionnaire consisted of scaled questions. The scaled questions included 4-point Likert scales and continuous rating scales (1, low/not similar, to 4, high/extremely similar) on the items related to evaluating the similarity of the strategic elements of purpose, objectives, and strategies. Five-point Likert-scale questions were used to evaluate Team Performance, both on the team-member survey and the separate instructor survey (1, low/poor, to 5, high/excellent). The team-member questionnaire was divided into categories related to the variables in the study: purpose, objectives, and strategies. Headings and numbering of questions were used to segregate the categories. In both surveys, definitions were provided for the key variables to aid in the understanding of the key concepts and variables in this research and to aid in the accuracy of the responses. Demographic information on the survey participants was collected on the team-members' survey.

The Team Survey instrument (see Appendix A) was divided into four parts and contained 14 questions. Part 1 and 4 were questions that collected team and student information respectively and required short, circled answers. Part 2 was composed of six questions related to Strategic Intent on 4-point Likert scales. Part 3 was composed of three questions related to Team Performance on 5-point Likert scales.

The Team Performance was also measured by the assigned DAU PMT 352B instructors. The Instructor Survey provided data for measuring the Instructor-assessed Team Performance. The first four questions on the Instructor Survey asked the instructors for data on the team's name, location of the class, and dates of the class. Question 4 asked the instructor to evaluate or assess the individual team's performance in accomplishing the course objectives. The instructors rated the teams on a 5-point Likert scale of poor (1) to excellent (5). Comments were also requested. The next section discusses the sample that was studied.

Research Sample Population

Fifty-seven data points or teams were collected from the population of teams enrolled in PMT 352B courses. The acquired empirical data from 12 PMT 352B classes were obtained from surveys conducted in the classroom from 57 student teams, their respective student members (327), and 32 team instructors. The students were Department of Defense (DoD) career acquisition professionals attending the technical training course (PMT 352B) at one of the five Defense Acquisition University campuses. This research was a co-sponsored DAU/Alliant International University research project. The instructors were certified DAU instructors, aged 35-60 years of age.

Demographic information was analyzed from the surveys also. Pearson's *r* correlation coefficient tests were used to test the correlation between team average age and team average years of experience to Strategic Intent, Team-assessed Team Performance, and Instructor-assessed Performance. Spearman's *rho* rank-order and Pearson's *r* correlation coefficient tests were used to determine the relationships between team educational levels to Strategic Intent, Team-assessed Team Performance, and Instructor-assessed Team Performance since the data (Educational Levels) were nominal data.

Overall Research Summary and Findings

Table 20 highlights the relative strength of each of the Pearson's *r* tests that were conducted in the study, including those identified in additional findings. Appendix B contains the actual SPSS test results. The italicized entries below identify the original 15 Research Question hypotheses, which were all supported at the .05 significance level with their *p*-values. All but the last entry (Question 9 to Instructor Performance) were supported at a .01 significance level. All the tests were supported at the .05 significance level.

For this paper, the following strength of the relationship or support was used: Pearson's r greater than .7 is considered a strong relationship; from .5 to .699 it is considered a moderate relationship; and from .3 to .499 it is considered a modest relationship/support.

Table 1. Relative Strength of Tested Variables in This Study

Variables	**Rank**	Pearson's *r*	*p*-value	**Results**
Question 8 (CO) TO Overall Strategic Intent	1	.921	.000**	Strongly Supported
Question 10 (CS) TO Overall Strategic Intent	2	.884	.000**	Strongly Supported
Question 7 (UO) TO Overall Strategic Intent	3	.880	.000**	Strongly Supported
Question 6 (CP) TO Overall Strategic Intent	4	.871	.000**	Strongly Supported
Question 9 (US) TO Overall Strategic Intent	5	.817	.000**	Strongly Supported
Question 5 (UP) TO Overall Strategic Intent	6	.793	.000**	Strongly Supported
Overall Strategic Intent TO Overall Team Performance	*7*	*.731*	*.000***	*Strongly Supported* *Hypothesis 1*
Overall Strategic Intent TO Question 11	8	.724	.000**	Strongly Supported
Overall Strategic Intent TO Question 12	9	.706	.000**	Strongly Supported
Overall Strategic Intent TO Question 13	10	.680	.000**	Moderately Supported

Variables	Rank	Pearson's *r*	*p*-value	**Results**
Question 10 (CS) TO Overall Team Performance	11	.673	.000**	Moderately Supported
Question 9 (US) TO Overall Team Performance	12	.671	.000**	Moderately Supported
Question 8 (CO) TO Overall Team Performance	13	.664	.000**	Moderately Supported
Question 7 (UO) TO Overall Team Performance	14	.662	.000**	Moderately Supported
Question 8 (CO) TO Question 12	*15*	*.658*	*.000***	*Moderately Supported* *Hypothesis 3b*
Question 7 (UO) TO Question 12	*16*	*.643*	*.000***	*Moderately Supported* *Hypothesis 3a*
Question 10 (CS) TO Question 13	*17*	*.640*	*.000***	*Moderately Supported* *Hypothesis 4b*
Instructor Performance TO Overall Team Performance	*18*	*.630*	*.000***	*Moderately Supported* *Hypothesis 7*
Question 9 (US) TO Question 13	*19*	*.625*	*.000***	*Moderately Supported* *Hypothesis 4a*
Question 6 (CP) TO Overall Team Performance	20	.604	.000**	Moderately Supported
Question 6 (CP) TO Question 11	*21*	*.594*	*.000***	*Moderately Supported* *Hypothesis 2b*

Variables	**Rank**	Pearson's *r*	*p*-value	**Results**
Question 5 (UP) TO Question 11	*22*	*.513*	*.000***	*Moderately Supported* *Hypothesis 2a*
Question 5 (UP) TO Overall Team Performance	23	.495	.000**	Modestly Supported
Question 10 (CS) TO Instructor Performance	*24*	*.486*	*.000***	*Modestly Supported* *Hypothesis 6f*
Question 7 (UO) TO Instructor Performance	*25*	*.466*	*.000***	*Modestly Supported* *Hypothesis 6c*
Overall Strategic Intent TO Instructor Performance	*26*	*.463*	*.000***	*Modestly Supported* *Hypothesis 5*
Question 8 (CO) TO Instructor Performance	*27*	*.405*	*.002***	*Modestly Supported* *Hypothesis 6d*
Question 6 (CP) TO Instructor Performance	*28*	*.352*	*.007***	*Modestly Supported* *Hypothesis 6b*
Question 5 (UP) TO Instructor Performance	*29*	*.349*	*.008***	*Modestly Supported* *Hypothesis 6a*
Question 9 (US) TO Instructor Performance	*30*	*.330*	*.012**	*Modestly Supported* *Hypothesis 6e*

Note: * Correlation is significant at the .05 level (two-tailed test); ** Correlation is significant at the .01 level (two-tailed test).

The first six entries/cases in the table above highlight the strongly supported relationship between the six individual questions in the team survey (Questions 6-10) and overall team Strategic Intent. These relationships are high in magnitude or strength because Team Strategic Intent is defined by the average of all the team members' responses to the six questions related to the team's understanding and commitment to the team's purpose (Questions 5 and 6 respectively), understanding and commitment to the team's objectives (Questions 7 and 8 respectively), and understanding and commitment to the team's strategies (Questions 9 and 10 respectively). These results make sense and provide no real insight into the research except that Question 8 (Team Understanding of Objectives) has the greatest strength of .921. This indicates that this question has the greatest effect on overall Team Strategic Intent. Managers should be aware that developing

a strong sense of understanding of team objectives among team members will have the most significant (largest) effect on the team's overall Strategic Intent perception. This can also have an effect on Team-assessed and Instructor-assessed Team Performance. This is consistent with the fact that Question 8 has the strongest relationship to Question 12 in terms of comparing Strategic Intent questions to their related Team Performance question. "Understanding the team objectives" as a variable plays a major role in both these relationships.

The strength of the relationship between overall Team Strategic Intent and Team Performance (Hypothesis 1) at .731 underscores the influence that strategic thinking or developing clear and understandable strategic elements in a team affects how the team will assess its performance. This is a vital source of information to educators, team and business leaders, and team sponsors/stakeholders. This highlights that a team with a clear set of strategic characteristics of a team purpose, objectives, and strategies will more probably develop a strong sense of being a high-performing team. Believing this will empower the team to greater team results and even more focused performance. This should also produce better results for the organizations that sponsor them. The leader of this team also needs to know that a focused, intent team will believe it will perform well.

Overall Team Strategic Intent is a key variable in this study and is analyzed/tested in 11 of the cases identified in Table 1 above. The strength of the relationship between Strategic Intent (SI) and Team Performance at .731 is compared to the same relationship between Strategic Intent and Instructor-assessed Performance at .463. This indicates that team strategic thinking has a greater relationship to or effect upon Team-assessed Team Performance than its effect on Instructor-assessed Performance. The strength of team Strategic Intent on the instructors' assessment is significant, nonetheless, and indicates that team strategic thinking not only affects Team Performance but also how the team's instructors assessed the team's performance.

Strategic Intent is a strong force in or predictor of team dynamics and development. Additional future studies should be made to understand how Team Strategic Intent is related to other indicators of team success or performance, such as quality of work, timeliness, problem-solving effectiveness, and overall team productivity. Overall Strategic Intent (SI) has a strong relationship not only to overall Team Performance at .731 but also when tested against the three questions that create Team Performance. The results are the following: 724 (Question 11 to SI), .706 (Question 12 to SI), and .680 (Question 13 to SI). This is to be expected and again underscores the strength and value of understanding the effects and strength of Team Strategic Intent on Team Performance. Additional Pearson's *r* correlation coefficient tests highlight that when the individual Strategic Intent questions (5-10) are compared to the overall Team-assessed Team Performance, significant (.01) relationships occur. In fact, the results of these tests are similar in strength to the results obtained on the tests between the Strategic Intent questions to their related individual Team-assessed Performance questions (11-13).

Here are the comparisons: Question 5, Understanding Team Purpose (Team Performance: .495; Question 11: .513); Question 6, Commitment to Team Purpose (Team Performance: .604; Question 11: .594); Question 7, Understanding Team Objectives (Team Performance: .662; Question 11: .643); Question 8, Commitment to Team Objectives (Team Performance: .664; Question 11: .658); Question 9, Understanding Team Strategies (Team Performance: .671; Question 11: .625); and Question 10,

Commitment to Team Strategies (Team Performance: .673; Question 11: .640). All of these results have p-values of .000**.

In summary, it is concluded that these additional tests on various Strategic Intent questions and overall Team-assessed Performance provided additional support to the previously conducted hypotheses tests. A more robust test was comparing the Strategic Intent questions (5-10) to the related Team-assessed Performance questions (11-13). The results moderately supported the direct relationship between these sets of variables. There was a moderately supported relationship between Team Strategic Intent and Team-assessed Performance with all three methods: (a) overall Team Strategic Intent to Overall Team Performance (Research Question 1 and Hypothesis 1), (b) results of individual Strategic Intent questions 5-10 to individual related Team Performance questions 11-13 (Research Questions 2a, 2b, 3a, 3b, 4a, and 4b), and (c) individual Strategic Intent questions 5-10 to overall Team Performance (see Table 20 results).

Additional Findings on Demographics Data

Additional tests were conducted on the measured demographic information and its relationship to overall team Strategic Intent, Team-assessed Team Performance, and Instructor-assessed Team Performance. Twelve tests were conducted, and only 3 tests were supported at least the .05 significance level. Two supported tests related Team Educational Level to Team-assessed Performance and to Instructor-assessed Team Performance. Pearson's *r* and Spearman's *rho* correlation tests both indicated a positive relationship between Team Educational Level and overall Team-assessed Team Performance and Instructor-assessed Team Performance at a .05 significance level.

Educational level can make a difference in Team Performance, both as assessed by the team itself and by the instructors. Although not significant at .05, there is also a positive effect on overall Team Strategic Intent by team Educational Level. Although not statistically significant, there does appear to be some indication that using teams is an effective learning technique in education, and business leaders employing teams in their organizations who want to enhance strategic implementation of corporate strategic goals and initiatives should be aware that teams with higher educational levels tend to have higher Team Strategic Intent (r = .239, not significant at .05), higher overall Team-assessed Team Performance (r = .296, p-value = .025*), and higher Instructor-assessed Team Performance (r = .441. p-value = .001**). Educational Level has a positive effect on these three research variables. Education has a rather significant effect on Instructor-assessed Team Performance (r = .441).

Team age and years of experience have a negative effect on Team Strategic Intent, on overall Team-assessed Team Performance, and on Instructor-assessed Team Performance. The strength of the relationships is low, and the significant levels are high. No relationship was supported at the .05 significance level. Although not supported statistically at an alpha of .05, this was of interest to the researcher. Age and experience have negative relationships to all the research variables: Strategic Intent, Team-assessed Team Performance, and Instructor-assessed Team Performance.

There is a moderately strong relationship between Team Experience and Team Age (r = .643, p-value = .001**). This is logical, and passed the common-sense test. The results do not affect this research but highlight the strength of the survey data to develop conclusions regarding the survey sample.

Conclusions

The main conclusions in this research are the following:

1. There is a statistically significant relationship between the overall team Strategic Intent and overall Team-assessed Team Performance. Teams that have high overall team Strategic Intent (team purpose, objectives, and strategies) also have high overall Team-assessed Team Performance.
2. There is a statistically significant relationship between the individual team Strategic Intent questions (5-10) and overall Team-assessed Team Performance. Teams that have high results on individual team Strategic Intent questions (5-10) also have high results on overall Team-assessed Team Performance.
3. There is a statistically significant relationship between the individual team Strategic Intent questions (5-10) and individual Team-assessed Team Performance questions (11-13). Teams that have high results on individual team Strategic Intent questions (5-10) also have high results on individual Team-assessed Team Performance questions (11-13).
4. There is a statistically significant relationship between the overall team Strategic Intent and overall Instructor-assessed Team Performance (Question 4). Teams that have high overall team Strategic Intent (team purpose, objectives, and strategies) also have high Instructor-assessed Team Performance (Question 4).
5. There is a statistically significant relationship between the individual team Strategic Intent questions (5-10) and individual Instructor-assessed Team Performance (Question 4). Teams that possessed high scores on each individual Question 5-10 dealing with team Strategic Intent also had high Instructor-assessed Team Performance.
6. There is a statistically significant relationship between the overall Team-assessed Team Performance (Questions 11-13) and overall Instructor-assessed Team Performance (Question 4). Teams that have high overall Team-assessed Team Performance (Questions 11-13) also have high Instructor-assessed Team Performance (Question 4).
7. There is a statistically significant relationship between the overall Team Educational Level and overall Instructor-assessed Team Performance (Question 4). Teams that have high overall Team Educational Level also have high Instructor-assessed Team Performance (Question 4). There is some indication (supported at .05 significance level) that there is also a relationship between the overall Team Educational Level and *both* overall Team-assessed Team Performance (Questions 11-13) (supported at .05 significance level) and overall Strategic Intent (Questions 5-10) (not supported at .05 significance level).
8. There is some indication (not supported at .05 significance level) that there is also an indirect or negative relationship between the overall Team Average Age and *all* of the following: (a) overall team Strategic Intent (Questions 5-10), (b) overall Team-assessed Team Performance (Questions 11-13), and (c) overall Instructor-assessed Team Performance (Question 4).

There is some indication (not supported at .05 significance level) that there is also an indirect or negative between the overall Team Average Years Experience and *all* the

following: (a) overall team Strategic Intent (Questions 5-10), (b) overall Team-assessed Team Performance (Questions 11-13), and (c) overall Instructor-assessed Team Performance (Question 4). The strengths of these relationships and significance levels do not allow for statistical significance of these relationships. The interesting aspect of these studies highlight that with more data and research, age and experience may have statistically significant negative effects on the research variables of overall team Strategic Intent, Team-assessed Team Performance, and Instructor-assessed Team Performance.

Concluding Statement

Teams can be a significant resource to business leaders and lead to greater program successes. Little empirical data exist on what strategic characteristics make teams more effective. Does a work team's success depend on how strategically focused or intent the team is? Do team-developed purpose, objectives, and strategies (strategic intent) have an effect on how well teams perform? This research study hypothesized and proved that work team strategic intent characteristics (team-developed purpose, objectives, and strategies) were directly or positively related to the performance of student work teams.

Significant positive correlation relationships were found in all 15 studied hypotheses between work team strategic intent and team performance as measured by team self-assessments and instructor assessments. Additionally, a positive correlation was found between the team self-assessment of performance and the instructors' assessment of the team performance.

The research provided significant empirical data on the positive correlation relationships between work team strategic intent and work team performance. It also defined the characteristics that were used to determine the strategic intent of a work team or any work unit. It created empirical support for Katzenbach and Smith's theories from their studies in *The Wisdom of Teams*: *Creating the High-performance Organization* (2003) on the success of real teams, based on being committed to a common purpose and performance goals. Additionally, it created a survey to measure the strategic intent of team members and teams in general. Finally, it introduced the study of strategic thinking or use of strategic intent as a method or process for evaluating team performance.

The complexity of team performance and the large number of future potential influences and additional areas of research needed on teams were highlighted in the research. This may help explain why so many organizations using teams in both the public and private sector today are having difficulty as they try to reposition themselves in an ever more turbulent environment and why teams are often not as effective or successful as possible.

Properly disciplined, focused, and integrated teams are the ones that become high-performing teams, and are considered "the most versatile unit organizations have for meeting both performance and challenges in today's complex world" (Katzenbach & Smith, 2003, p. xiii). This study has identified that Strategic Intent or clearly focused team purpose, objectives, and strategies can make teams more high-performing and even more versatile and effective in an organization—both in the short and long term.

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Appendix A. Team Survey

WORK TEAM
INTENT AND WORK TEAM
PERFORMANCE

This is a university doctorate-level and Defense Acquisition University co-sponsored survey. It will contribute to advancing the body of knowledge to help identify if and how much the alignment of work team strategic intent (which relates to work team purpose, objectives, and strategies) contribute to work team performance. This information will help enhance work team performance effectiveness in DAU classrooms and in DoD organizations.

The information gathered in this questionnaire is confidential. No specific response will be shared with any respondent. Only aggregate information will be discussed in this study. No specific information about you personally or your team will be released.

The survey is optional. If you do not want to complete the survey inform the researcher or instructor that is administering the survey.

<u>Consent:</u> Your completion of this survey and submittal to the researchers provide your consent to the researcher to use the data in the survey to conduct analyses and determine the results and conclusions related to their research.

<u>Additional Information, Completed Surveys, and Requests for Results of this Research Should be Sent to:</u>

Tom Edison
Alliant International University
536 H Ave
Coronado, Calif. 92118
Tel: 619-437-4123 (Home)
619-524-4815 (Work)
tom.edison@dau.mil

Thank you very much for your cooperation!

<u>Work Team Information</u>

Please fill in the blanks below:

1. Name and/or number assigned to your work team: ________________________________.

2. Date (month/day/yr) your work team began its work (date class began) and ended: class began from ________________ and lasted to ________________.

3. Specific stated purpose/charter of your work team: ____ ____

4. Location of your class/team: ____.

Questions 5 to 10 that follow ask for your judgment or perception on how similar or aligned your understanding of and/or commitment to specific work team elements (purpose, objectives, and strategies) are to those of other members on your work team.

<u>Purpose</u>

Questions 5 to 6: Team's *<u>purpose</u>* refers to your work team's overall goal for the future of the work team during next six weeks. Consider this as your intent or focus that collectively provided the work team a future goal for the team's activities and affected the team's decision making and performance.

5. How similar is your <u>understanding</u> of your work team's ***purpose*** to that of the other members on your work team? (Circle correct rating.)

Your Understanding of Work Team's Purpose	**Not Similar at all**	**Somewhat Similar**	**Very Similar**	**Extremely Similar**
	1	2	3	4

6. How similar is your commitment to your work team's ***purpose*** to that of the other members on your work team? (Circle correct rating.)

Your Commitment to Work Team's Purpose	**Not Similar at all**	**Somewhat Similar**	**Very Similar**	**Extremely Similar**
	1	2	3	4

Objectives

Questions 7 to 8: Team's *objectives* are the specific work team performance targets or shorter-term targets your work team was formed for and is working to accomplish.

7. How similar is your understanding of your work team's ***objectives*** to that of the other members on your work team? (Circle correct rating.)

Your Understanding of Team's Objectives	**Not Similar at all**	**Somewhat Similar**	**Very Similar**	**Extremely Similar**
	1	2	3	4

8. How similar is your commitment to your work team's ***objectives*** to that of the other members on your work team? (Circle correct rating.)

Your Commitment to Team's Objectives	**Not Similar at all**	**Somewhat Similar**	**Very Similar**	**Extremely Similar**
	1	2	3	4

Strategies

Questions 9 to 10: Team's *strategies* are work team procedures, plans, approach, and methods used to achieve the overall work team's purpose and objectives.

9. How similar is your understanding of your work team's ***strategies*** to that of the other members on your work team? (Circle correct rating.)

Your Understanding of Team's Strategies	**Not Similar at all**	**Somewhat Similar**	**Very Similar**	**Extremely Similar**
	1	2	3	4

10. How similar is your commitment to your work team's ***strategies*** to that of the other members on your work team? (Circle correct rating.)

Your Commitment to Team's Strategies	**Not Similar at all**	**Somewhat Similar**	**Very Similar**	**Extremely Similar**
	1	2	3	4

TEAM PERFORMANCE

Questions 11-13: Team *performance* relates directly to your team's accomplishment of the team's purpose (evaluated in questions 5-6) and objectives (evaluated in questions 7-8) using the team strategies (evaluated in questions 9-10).

11. Please indicate how you rate your work team's overall **performance** in terms of accomplishing your work team's purpose. (Circle one rating number that represents the success of team accomplishments in relation to your team purpose.)

Poor	Below Ave	Average	Good	Excellent
1	2	3	4	5

12. Please indicate how you rate your work team's overall **performance** in terms of accomplishing your work team's objectives. (Circle one rating number that represents the success of team accomplishments in relation to your team objectives.)

Poor	Below Ave	Average	Good	Excellent
1	2	3	4	5

13. Please indicate how you rate your work team's overall **performance** in terms of using your work team's strategies. (Circle one rating number that represents the success of team accomplishments in relation to using your team strategies.)

Poor	Below Ave	Average	Good	Excellent
1	2	3	4	5

Personal Information

(This information will be held in strictest confidence. Please fill in the blanks below.)

14. In the following questions please provide some ***personal information*** about yourself:

a. **Total years work experience**: ______years (Fill in the blank)

b. **Gender**: Male Female (Circle correct answer)

c. **Your age:**_____________(Fill in the blank)

d. **Current work status**:

1. If active duty military answer below: (Circle answer or check in box)

In what Service were you on active duty on January 2, 2006?

Army

Navy

Marine Corps

Air Force

2. If government civilian answer below: (Circle answer or check in box)

For which Department of Defense (DoD) component did you work on January 2, 2006?

Army

Navy

Marine Corps

Air Force

DoD Agency or Activity

3. If civilian contractor answer below: (Fill in blank)

What company do you work for? ________________________

f. Work/functional background that you've worked more than 50% of your total career time. (Check one most correct)

_____Engineering

_____Logistics

_____Sales

_____Marketing

_____Quality Assurance

_____Program Management

_____Operations

_____Contracting

_____Procurement

_____Provisioning/Supply

_____Financial Management

_____Information Technology

_____Software Management

_____Other (Write in Work Background greater than 50%)

____

g. Highest educational level completed: (Circle most correct choice)

1	Some High School		6	Some Post-Graduate Courses
2	High School Graduate		7	Masters Degree
3	Some College (1-2 yrs)		8	Some Post-Masters Courses
4	Some College (3-4 yrs)		9	PhD/Doctorate Degree
5	Bachelors, College Graduate		10	Other___________________

Thank you very much for your help with this research project!

Comments or Recommendations:

Appendix B. Overall Test Results

1. Correlation Results of Overall Strategic Intent and Overall Team-assessed Performance—(RQ 1)

Correlations

		a	TeamPerf
a	Pearson Correlation	1	.731**
	Sig. (2-tailed)		.000
	N	57	57
TeamPerf	Pearson Correlation	.731**	1
	Sig. (2-tailed)	.000	
	N	57	57

**. Correlation is significant at the 0.01 level (2-tailed).

2. Correlation Results of Strategic Intent Elements (Q 5-10) to Work Team-assessed Performance (Q 11-13)—(RQ 2a-b, 3a-b & 4a-b):

Descriptive Statistics

	Mean	Std. Deviation	N
Q5TUP	3.2120	.33203	57
Q6TCP	3.2104	.32512	57
Q7TUO	3.2141	.32723	57
Q8TCO	3.1840	.37275	57
Q9TUS	3.0389	.34556	57
Q10TCS	3.1209	.36104	57
Q11PP	4.3788	.45923	57
Q12PO	4.3041	.47522	57
Q13PS	4.1885	.47659	57

Correlations

		Q5TUP	Q6TCP	Q7TUO	Q8TCO	Q9TUS	Q10TCS	Q11PP	Q12PO	Q13PS
Q5TUF	Pearson Corre	1	.652**	.704**	.675**	.564**	.525**	.513**	.452**	.464**
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.000	.000	.000
	N	57	57	57	57	57	57	57	57	57
Q6TCF	Pearson Corre	.652**	1	.649**	.860**	.587**	.756**	.594**	.562**	.589**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.000	.000	.000
	N	57	57	57	57	57	57	57	57	57
Q7TUC	Pearson Corre	.704**	.649**	1	.786**	.699**	.718**	.663**	.643**	.608**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000	.000	.000
	N	57	57	57	57	57	57	57	57	57
Q8TCC	Pearson Corre	.675**	.860**	.786**	1	.622**	.803**	.677**	.658**	.585**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.000	.000	.000
	N	57	57	57	57	57	57	57	57	57
Q9TUS	Pearson Corre	.564**	.587**	.699**	.622**	1	.747**	.635**	.677**	.625**
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000	.000	.000
	N	57	57	57	57	57	57	57	57	57
Q10TC	Pearson Corre	.525**	.756**	.718**	.803**	.747**	1	.655**	.648**	.640**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000	.000	.000
	N	57	57	57	57	57	57	57	57	57
Q11PP	Pearson Corre	.513**	.594**	.663**	.677**	.635**	.655**	1	.928**	.877**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000		.000	.000
	N	57	57	57	57	57	57	57	57	57
Q12PC	Pearson Corre	.452**	.562**	.643**	.658**	.677**	.648**	.928**	1	.864**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000		.000
	N	57	57	57	57	57	57	57	57	57
Q13PS	Pearson Corre	.464**	.589**	.608**	.585**	.625**	.640**	.877**	.864**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	
	N	57	57	57	57	57	57	57	57	57

**. Correlation is significant at the 0.01 level (2-tailed).

3. Correlation Results of Overall Strategic Intent and Overall Instructor-assessed Performance—(RQ 5):

Correlations

		a	Q14InstrPerf
a	Pearson Correlation	1	.463**
	Sig. (2-tailed)		.000
	N	57	57
Q14InstrPerf	Pearson Correlation	.463**	1
	Sig. (2-tailed)	.000	
	N	57	57

**. Correlation is significant at the 0.01 level (2-tailed).

4. Correlation Results of Strategic Intent Elements (Q5-10) to Instructor Assessed Performance—(RQ 6a-f):

Correlations

		Q5TUP	Q6TCP	Q7TUO	Q8TCO	Q9TUS	Q10TCS	Q14InstrPerf
Q5TUP	Pearson Correlation	1	.652**	.704**	.675**	.564**	.525**	.349**
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.008
	N	57	57	57	57	57	57	57
Q6TCP	Pearson Correlation	.652**	1	.649**	.860**	.587**	.756**	.352**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.007
	N	57	57	57	57	57	57	57
Q7TUO	Pearson Correlation	.704**	.649**	1	.786**	.699**	.718**	.466**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000
	N	57	57	57	57	57	57	57
Q8TCO	Pearson Correlation	.675**	.860**	.786**	1	.622**	.803**	.405**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.002
	N	57	57	57	57	57	57	57
Q9TUS	Pearson Correlation	.564**	.587**	.699**	.622**	1	.747**	.330*
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.012
	N	57	57	57	57	57	57	57
Q10TCS	Pearson Correlation	.525**	.756**	.718**	.803**	.747**	1	.486**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000
	N	57	57	57	57	57	57	57
Q14InstrPerf	Pearson Correlation	.349**	.352**	.466**	.405**	.330*	.486**	1
	Sig. (2-tailed)	.008	.007	.000	.002	.012	.000	
	N	57	57	57	57	57	57	57

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

5. Correlation Results of Overall Team-assessed Performance and Overall Instructor Assessed Performance—(RQ 7):

Correlations

		TeamPerf	Q14InstrPerf
TeamPerf	Pearson Correlation	1	.630**
	Sig. (2-tailed)		.000
	N	57	57
Q14InstrPerf	Pearson Correlation	.630**	1
	Sig. (2-tailed)	.000	
	N	57	57

**. Correlation is significant at the 0.01 level (2-tailed).

Panel 5 - Open Architecture, Open Business Models and Collaboration for Acquisition

Wednesday, May 16, 2007	Panel 5 - Open Architecture, Open Business Models and Collaboration for Acquisition
1:45 p.m. – 3:15 p.m.	**Chair:** **William Bray**, Program Manager Integrated Combat Systems, PEO IWS **Discussant:** **Nickolas H. Guertin,** Deputy Director Naval Open Architecture **Papers:** ***AEGIS and Ship Self-Defense System (SSDS) Platforms: Using KVA Analysis, Risk Simulation and Strategic Real Options to Assess Operational Effectiveness*** **Thomas Housel, Johnathan Mun, Eric Tarantino,** and **Maj Scott Uchytil, USMC,** Naval Postgraduate School ***Measuring the Value Added of Management: A Knowledge Value Added Approach*** **Thomas Housel, Valery A. Kanevsky,** Naval Postgraduate School

AEGIS and Ship Self-defense System (SSDS) Platforms: Using KVA Analysis, Risk Simulation and Strategic Real Options to Assess Operational Effectiveness

Presenter: Dr. Thomas Housel, PhD**,** specializes in valuing intellectual capital, telecommunications, information technology, value-based business process reengineering, and knowledge value measurement in profit and non-profit organizations. He is currently a tenured Full Professor for the Information Sciences (Systems) Department. His current research focuses on the use of "Real Options" models in identifying, valuing, maintaining, and exercising options in military decision-making. Prior to joining NPS, he also was a Research Fellow for the Center for Telecommunications Management and Associate Professor at the Marshall School of Business at the University of Southern California. Housel has been the Chief Business Process Engineer for Pacific Bell, where he completed numerous reengineering projects and developed a new objective method for objectively measuring the value-added by reengineering. His last assignment in the corporate world was as the Chief of Consumer Market Research for Telecom Italia in Venice, Italy, where he developed new methods for predicting the adoption rates for new interactive multimedia broadband applications. He is Managing Partner for Business Process Auditors, a firm that specializes in training Big Six consultants, large manufacturing and service companies in the Knowledge Value-Added methodology for objectively measuring the return generated by corporate knowledge assets/intellectual capital. He received his PhD from the University of Utah in 1980. He won the prestigious Society for Information Management award for best paper in the field in 1986. His work on measuring the value of intellectual capital has been featured in a *Fortune* cover story (October 3, 1994) and *Investor's Business Daily*, numerous books, professional periodicals, and academic journals (most recently in the *Journal of Intellectual Capital,* vol 2., 2005). His latest books include: *Measuring and Managing Knowledge* and *Global Telecommunications Revolution: The Business Perspective* with McGraw-Hill (both in 2001).

Presenter: Dr. Johnathan Mun, PhD, MBA, MS, CFC, CRA, FRM, MIFC. Dr. Johnathan C. Mun is a Research Professor at the Naval Post Graduate School and is the CEO of Real Options Valuation LLC, a consulting, training, and software development firm specializing in real options, employee stock options, financial valuation, and risk analysis located in Northern California. He is the creator of the *Real Option Super Lattice Solver* software, Monte Carlo *Risk Simulator* software, and *Employee Stock Options Valuation* software at the firm. The *Employee Stock Options Valuation* software was used by the Financial Accounting Standards Board (FASB) to develop their example valuation (A87) in the 2004 FAS 123 requirements (he has also advised the Board of Directors at FASB on several occasions on binomial and options valuation). He has authored numerous books including *Real Options Analysis: Tools and Techniques* (Wiley 2002, with a second edition forthcoming September 2005), *Real Options Analysis Course* (Wiley 2003), *Applied Risk Analysis* (Wiley 2003), and *Valuing Employee Stock Options* (Wiley 2004). His books and software are being used around the world at top universities (including the Bern Institute in Germany, Chung-Ang University in South Korea, Georgetown University, ITESM in Mexico, Massachusetts Institute of Technology, New York University, Stockholm University in Sweden, University of the Andes in Chile, University of Chile, University of Pennsylvania Wharton School, University of York in the United Kingdom, and Edinburgh University in Scotland, among others.

He has been a finance and economics professor and has taught courses in financial management, investments, real options, economics, and statistics at the undergraduate and the graduate MBA levels. He has taught at universities all over the world, from the University of Applied Sciences (Switzerland and Germany) and St. Mary's College (California), and has chaired many graduate research thesis committees. He was formerly the Vice President of Analytics at Decisioneering, Inc., where he headed up the development of real options and financial analytics software products, analytical consulting, training, and technical support, and where he was the creator of the Real Options Analysis Toolkit software, the predecessor of the Super Lattice Software discussed in this book. Prior to joining Decisioneering, he was a Consulting Manager and Financial Economist in the Valuation Services and Global Financial Services practice of KPMG Consulting and a Manager with

the Economic Consulting Services practice at KPMG LLP. He has extensive experience in econometric modeling, financial analysis, real options, economic analysis, and statistics.
He has most recently been working on Department of Defense (DoD) projects that apply real options—integrated risk management to support analysis of alternatives, strategic courses of action, and acquisitions programs. He has, with Dr. Tom Housel of the Naval Post Graduate School, developed a 5-day intensive training course to teach DoD analysts and managers how to apply the real options analysis technique to various decision making problems. He has also developed a module for the Homeland Defense technology class for the masters program at the Naval Post Graduate School.
Dr. Mun received his PhD in Finance and Economics from Lehigh University, where his research and academic interests were in the areas of Investment Finance, Econometric Modeling, Financial Options, Corporate Finance, and Microeconomic Theory. He also has a MBA in business administration, a MS in management science, and a BS in Biology and Physics. He is Certified in Financial Risk Management (FRM), Certified in Financial Consulting (CFC), and is Certified in Risk Analysis (CRA). He is a member of the American Mensa, Phi Beta Kappa Honor Society, and Golden Key Honor Society as well as several other professional organizations, including the Eastern and Southern Finance Associations, American Economic Association, and Global Association of Risk Professionals. Finally, he has written many academic articles published in the *Journal of the Advances in Quantitative Accounting and Finance,* the *Global Finance Journal,* the *International Financial Review,* the *Journal of Financial Analysis,* the *Journal of Applied Financial Economics,* the *Journal of International Financial Markets, Institutions and Money,* the *Financial Engineering News,* and the *Journal of the Society of Petroleum Engineers.*
Presenter: Eric Tarantino, is a recent graduate of the University of Virginia. He graduated as a Bachelor of Arts with High Distinction, receiving majors in both Anthropology and Economics. Currently he works as a research associate at the Naval Postgraduate School where he focuses on valuation studies for the Department of Defense (DoD). After receiving his certification in Risk Management (CRM) from the International Institute of Professional Education and Research (IIPER), Eric has aided in many studies including: assessing the return on investment of various options for upgrading the AEGIS weapons system; analyzing the SHIPMAIN program and projecting its potential value added when three dimensional visualization and product lifecycle management collaborative tools are used; an efficiency study of the Army’s Rapid Equipping Force, rapid acquisition process; and will soon be a coauthor of a book chapter discussing the SHIPYARD Planning Process. His work focuses on the use of the Knowledge Value Added methodology coupled with Real Options analysis. Eric is also training to become a professional Scuba Diver.

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Abstract

Modern, analytical tools are critical to understand the impact of open architecture technology and open business models on naval warfighting processes and procedures. These tools must measure the operational value of a system from an end-user, warfighter

perspective, identify areas of deficiencies in capabilities, and flag areas for potential acquisitions. One advantage of examining open architected system upgrade options from a warfighter perspective is that the new systems can be integrated with reengineered processes more easily leading to improved process performance. This perspective, using OA to upgrade existing IWS systems, ensures that upgrades will lead to improved warfighting capabilities. Traditional measurement tools used for cost analysis cannot calculate the *total value* of upgrading a system to support an improved warfighting capability, particularly the improved operational value resulting from reengineering of warfighting processes.

The Knowledge Value Added/Real Options (KVA+RO) Valuation Framework is a tool designed to assist decision-makers in making technology acquisitions. This paper describes research using the KVA+RO framework for estimating return on investment, in an open architecture approach, to upgrading and/or replacing aging IWS AEGIS and SSDS systems. The results of the research indicated that using the open architecture (OA)model, in combination with the "leave and layer" approach, was approximately five times more valuable than the current proprietary approach to system replacement and was approximately twice as valuable as a complete retrofit and replace strategy. "Leave and layer" provided the highest return on investment for replacing the AEGIS system with the lowest risk. The ultimate success of the OA approach is dependent on the ability of the multiple parties to system development and deployment to collaborate. Collaboration, along with the tools that facilitate collaboration, is critical to the success of any of the OA approaches.

Keywords: Return on Investment, Real Options, AEGIS, SSDS, Integrated Risk Management

Acknowledgements

We would like to acknowledge all the help and guidance Captain Jim Shannon, Bill Johnson, and Mark Wessman provided throughout this very complex research process. Without their help, we never would have been able to collect and refine the data we needed for our KVA + RO analysis. We would also like to thank RADM (retired) Jim Greene for his continued help and support for our research efforts with Open Architecture in the context of the AEGIS IWS. Jim's guidance on the cost structure of the AEGIS system and timing of its deployment were critical in increasing the accuracy of our analysis.

Executive Summary

The US Navy (Navy) is transforming traditional business practices through Naval Open Architecture (Naval OA). Naval OA, a multi-faceted, enterprise-wide business model and product-line strategy leverages “open” computer design principles and architectures. It expands the technological open architecture (OA) model and taps into a multiple-developer network to deliver cost-effective, innovative, and rapid/spiral acquisition capabilities. In the migration to an OA business model, billions of dollars in software and hardware development expenditures, along with subsequent maintenance costs, are at stake.

PEO IWS tasked a research team from the Naval Postgraduate School (NPS) to develop a methodology for estimating return on investment (ROI) using an OA approach to upgrading and/or replacing the aging Integrated Weapons Systems (IWS) AEGIS and SSDS systems. The methodology also had to be capable of estimating total value of strategic alternative options for replacing existing AEGIS functionality.

Approaching the project from a customer-based, warfighter perspective, the NPS team applied the Knowledge Value Added/Real Options (KVA+RO) valuation/risk portfolio management framework to reengineering situational awareness (SA) procedures used in the AEGIS and SSDS platforms.[7] Track management sub-processes used in SA procedures were analyzed through the KVA process reengineering methodology under “As Is,” “To Be,” “Radical 1,” and Radical 2” scenarios. ROI metrics on individual sub-processes and watch stations for AEGIS and SSDS were generated through KVA, with a particular focus on systems interoperability. ROI estimates reached as high as 404% for AEGIS and 399% for SSDS.

Real options analysis was then performed to determine the prospective value of upgrading the AEGIS IWS over a nine-year period from KVA data inputs. Three options of “Strategy A: As Is” (i.e., maintain the existing proprietary approach), “Strategy B: DDX OA—Develop and Retrofit” (i.e., develop a complete system using an OA approach and replace the existing AEGIS system), and “Strategy C: Aegis OA—Leave and Layer” (i.e., use an OA approach and replace AEGIS modules over time) represent potential system development and deplolyment strategies; each a unique path with risks and benefits. Real Options values ranged from $12 billion to $58.8 billion for the strategic choices.

The KVA+RO Framework

KVA+RO is a comprehensive measurement process and an integrated tool set that defines, measures and evaluates the total value of given IWS acquisitions. It captures data across a spectrum of organizations to compare returns on investments, outputs, processes, capabilities, risks, strategic alternatives, costs, and value (i.e., comparable revenue). KVA+RO analytically quantifies uncertainty and risks elements inherent in predicting the future, includes ways to mitigate these risks through strategic options with analysis of alternatives, and by analytically developing and allocating budgets to optimize project portfolios.

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[7] Although the total functionalities of AEGIS and SSDS IWS systems are so broad, we focused on situational awareness because it is the most promising area for upgrading and reengineering.

Knowledge-based Metrics: Knowledge Value Added (KVA)

KVA measures the value provided by human capital assets and IT assets by an organization, process or function at the sub-process level. Using a “market comparables” valuation technique, it monetizes the outputs of all assets, including intangible knowledge assets. Using market comparables provides a means for valuing the outputs of warfighting processes in the common units of money. This, in turn, makes it possible to use powerful financial metrics in forecasting the value of various strategic options for replacing aging IWS systems.

Capturing the value embedded in an organization’s core processes, employees and IT enables the actual cost and revenue of a product or service to be calculated. Analyses like ROI on individual projects, programs, processes and sub-processes within a portfolio of IT acquisitions can be derived through the KVA methodology.

Risk Analysis: Real Options (RO)

Potential strategic investments can then be evaluated with real options analysis based on KVA data. The analysis applied is a robust and analytical process incorporating the risk identification (applying various sensitivity techniques), risk quantification (applying Monte Carlo simulation), risk valuation (applying real options analysis), risk mitigation (utilizing real options framing), and risk diversification (employing analytical portfolio optimization).

Study Results and Recommendations Summary

The results of our analysis include:

- ***The KVA+RO valuation framework, a viable methodology for estimating ROIs and projecting valuation of acquisition options, should be used across the board.*** Several Department of Defense projects are implementing the framework. The methodology also supports the CNO’s recent directive of accelerating adoption of open-business models and providing a methodology to assess the business risks and benefits of various OA-based acquisition strategies.

- Upgrading existing IWS functionality to support reengineering elements of existing track-management process appears beneficial. ROIs ranged from 212% to 404% for the AEGIS platform and ROIs for the SSDS platform were also significant. ROI results are shown in Figures 1 and 2.[8] In addition, Tables 1 and 2 provide a detailed analysis of the ROIs for reengineering the track management process. Table 3 summarizes the reengineered processes and subsequent benefits. The results are based on the assumption that the IWS systems could be developed within an OA framework to support the reengineered process designs.

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[8] Radical 1 scenario assumes the improvements of the “To Be” scenario while the Radical 2 scenario assumes cumulative improvements from all three scenarios.

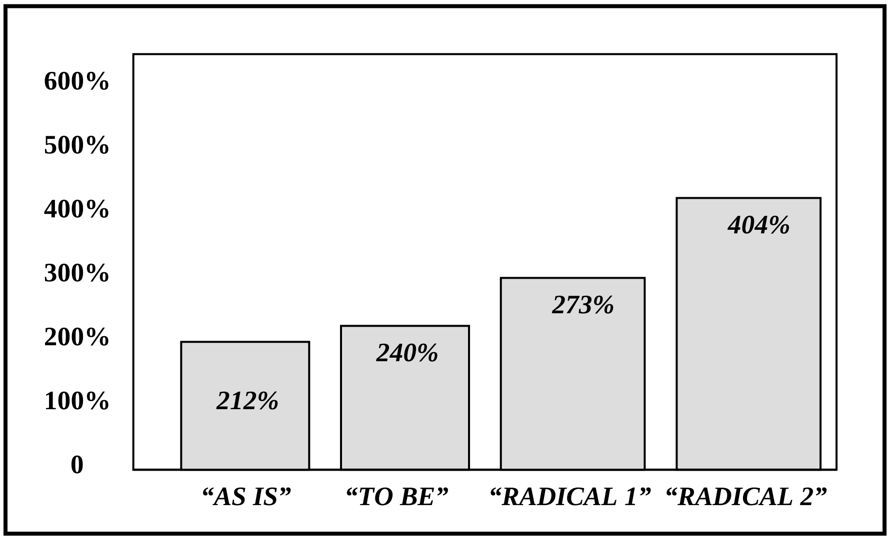

Figure 1. KVA Results: AEGIS ROI Estimates

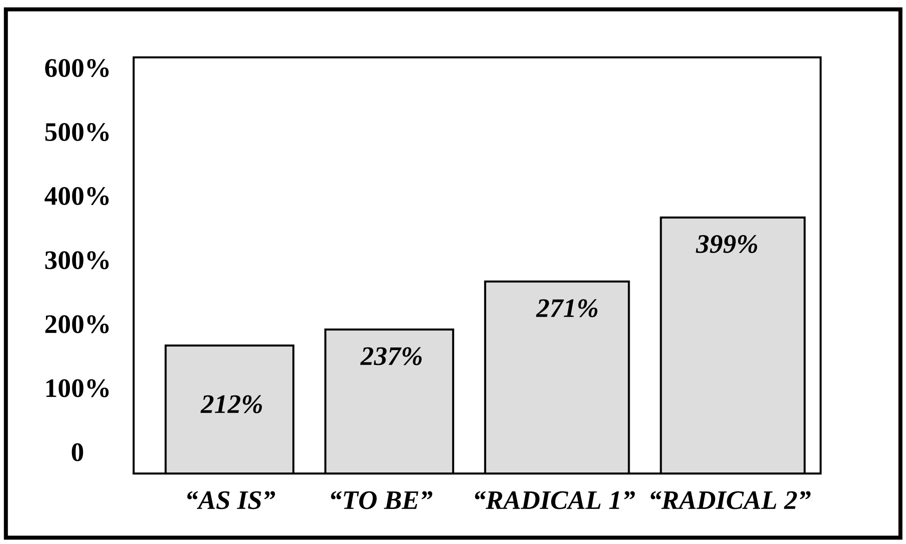

Figure 2. KVA Results: SSDS ROI Estimates

Tables 1 and 2 are more detailed results for ROI analysis for "As Is" and the other three increasingly automated scenarios.

	AS IS	TO BE	RAD 1	RAD 2
CORRELATE				
Obtain Link Information	3421%	3307%	3063%	2633%
Identify "Same Contact, Multiple Track"	-91%	-91%	2061%	1756%
Verify Other Track Sources	-95%	-95%	-95%	-96%
Correlate sub-total	***1184%***	***1141%***	***1506%***	***1296%***
TRACK				
Monitor Suspect Tracks	-98%	-99%	-99%	-99%
Update Tracks	-97%	-97%	361%	310%
Update GCCS-M	-97%	91%	84%	69%
Track sub-total	***-98%***	***-94%***	***-58%***	***-64%***
IDENTIFY				
Verify IFF signal	802%	769%	706%	607%
Verify EW emissions	-91%	-91%	-92%	509%
Verify Point of Origin	-98%	4121%	3821%	3332%
Match Against ATO	-98%	4206%	3890%	3382%
Match Against CommAir Profile	863%	835%	763%	643%
Match Against Intel Information	-97%	-97%	-97%	3814%
Examine Kinematic Data	-96%	-96%	-97%	-97%
Obtain Visual ID	-100%	-100%	-100%	-100%
Conduct Verbal Query	-99%	-99%	-99%	-99%
Identify sub-total	***8%***	***60%***	***50%***	***326%***
RELAY				
Send Over Links	-87%	-88%	-89%	-90%
Discuss Picture with Battle Force Units	-98%	-99%	-99%	-99%
Relay sub-total	***-97%***	***-98%***	***-98%***	***-99%***
Totals	**212%**	**240%**	**273%**	**404%**

Table 1. Detailed ROI Estimates for AEGIS

	AS IS	TO BE	RAD 1	RAD 2
CORRELATE				
Obtain Link Information	3393%	3280%	3026%	2598%
Identify "Same Contact, Multiple Track"	-91%	-91%	2530%	2158%
Verify Other Track Sources	-95%	-95%	-96%	-96%
Correlate sub-total	***1174%***	***1131%***	***1512%***	***1301%***
TRACK				
Monitor Suspect Tracks	-98%	-99%	-99%	-99%
Update Tracks	-96%	-97%	546%	475%
Update GCCS-M	-98%	14%	10%	1%
Track sub-total	***-98%***	***-96%***	***-53%***	***-60%***
IDENTIFY				
Verify IFF signal	790%	757%	692%	595%
Verify EW emissions	-90%	-91%	-91%	474%
Verify Point of Origin	-98%	3689%	3405%	2967%
Match Against ATO	-98%	3813%	3510%	3049%
Match Against CommAir Profile	926%	896%	816%	688%
Match Against Intel Information	-97%	-97%	-97%	3688%
Examine Kinematic Data	-96%	-96%	-96%	-96%
Obtain Visual ID	-100%	-100%	-100%	-100%
Conduct Verbal Query	-99%	-99%	-99%	-99%
Identify sub-total	***12%***	***59%***	***48%***	***316%***
RELAY				
Send Over Links	-82%	-83%	-84%	-86%
Discuss Picture with Battle Force Units	-99%	-99%	-99%	-99%
Relay sub-total	***-97%***	***-98%***	***-98%***	***-98%***
Totals	**212%**	**237%**	**271%**	**399%**

Table 2. Detailed ROI Estimates for SSDS

Table 3 discusses the potential impact of an OA approach on AEGIS and SSDS.

	"As Is"	**"To Be"**	**"Radical 1"**	**"Radical 2"**
	None	Limited re-engineering	Significant re-engineering	Substantial re-engineering
Technology Impact	**None**	• Info provided in ATO could be upgraded into AEGIS, reducing manpower requirements. • Enables greater sensor and data integration, providing enhanced correlation in pinpointing origin of aircraft or ship.	• Streamlined system automatically updates tracks. • Increased information-sharing and collaborative technology allows for automatic correction of multiple tracks per target. • Continuously updates tracks, allowing for pinpoint accuracy. • Collaborative technology minimizes possibility of multiple tracking of targets. • Includes changes from "To Be"	• Collaborative technology automatically updates ship's systems with Intel information. • Electronic communication of data from EW to CIC personnel facilitates COTS-based environment that easily upgrades to accommodate greater processor speeds. • Greatly enhances CIC efficiency through more timely SA. • Includes changes from "To Be" and "Radical 1."
Potential Benefits*	------	• Reduces maintenance costs. • Frees watch-standers to perform other tasks while providing faster data flow.	• Increases accuracy of tracking targets.	• Substantial re-engineering leads to drastic reduction in watch-stander work time, greatly reducing human error and further decreasing maintenance costs.

Table 3. Potential Benefits of OA Combined with Reengineering of Track Management Operations

- ***Strategy C: Leave and Layer is the most promising strategy with lowest total costs.*** It has the highest potential rate of return with a valuation of $58.8 billion and 4.9 times the potential return than Strategy A. Strategy B has a valuation of $23.2 billion, while Strategy A has the lowest valuation at $12 billion.

Table 4. Real Options Valuation Results: Strategies A-C

	Strategy A	Strategy B	Strategy C
STRATEGIC OPTION	"As Is"	DDX OA "Develop and Retrofit"	AEGIS OA "Leave & Layer"
Net Present Value	$12.00B	$6.38B	$27.52B
Real Options Value	$12.00B	$23.16B	$58.84B
Total Cost	$10.00B	$24.00B	$9.09B
Strategic Real Options-based Relative Return Ratio	1.00	1.9	4.9

- ***Collaboration is critical.*** OA as an acquisition, development and deployment framework will not succeed without the support of a collaborative infrastructure to facilitate the introduction of multiple large, medium and smaller players and their necessary interactions with users of the systems (e.g., warfighters), the acquisition community, and Navy leadership. Significant investments will be required for the infrastructure necessary to enable all parties (acquirers, users, developers) to collaborate easily and effectively in an OA model.

- ***Performance monitoring is required.*** If the performance of acquisition strategies is not monitored over time, the probability of success will be greatly reduced. Performance measurement systems (i.e. performance accounting software), in conjunction with predictive forecasting software programs, provide additional analytic support to IWS systems-acquisition strategies.

These research results, along with components of the KVA+RO framework and key findings from the analysis, are summarized in this report.[9]

Summary

IWS systems developed in a closed, proprietary model have performed well and provide substantial returns. However, a new paradigm is required to maintain military superiority and wage information-age warfare. Through open architected system development and open-business models, benefits such as reusable code, lower maintenance-upgrade costs, and greater vendor flexibility in supporting system module upgrades could be derived. Moreover, the Navy can leverage new technology by quickly adopting it to warfighter needs.

This study found that the "leave and layer" option for IWS replacement provided the lowest costs, highest ROIs, and highest strategic options value with the lowest risk. The

[9] The accuracy of our analysis is dependent on data and information provided by subject-matter experts. KVA analysis includes tests of the reliability of their estimates.

results recommend use of the OA—leave and layer IWS replacement approach to support reengineered warfighting processes.

Introduction

Naval Open Architecture (Naval OA) is a multi-faceted, enterprise-wide business model and product-line strategy designed to fully capitalize on "open" computer design principles and architectures. Expanding on the technological open architecture (OA) model, Naval OA leverages, "open business models for the acquisition and spiral development of new systems that enable multiple developers to collectively and competitively participate in cost-effective and innovative capability delivery to the Naval Enterprise" (Mullen, 2006, August 28). The new OA business model requires a greater degree of collaboration among customers (e.g., warfighter), builders (e.g., small, medium, and large technology companies), and buyers (e.g., the acquisition community) than the existing closed, proprietary IWS business model. In the migration to an OA business model, billions of dollars in hardware and software development expenditures, along with subsequent maintenance costs, are at stake.

To understand the potential impact of OA technology and business models on naval warfighting processes and procedures, analytical tools are critical for decision-makers as they manage their portfolio of options. Portfolio management requires that these tools quantify the risks, costs, and net value of potential IWS acquisitions. The tools must be able to help identify where gaps exist in current processes and to project anticipated returns on investments to fill those gaps.

This study describes research conducted at the Naval Postgraduate School (NPS) using the Knowledge Value Added/Real Options (KVA+RO) valuation/risk portfolio management framework. KVA+RO is a comprehensive measurement tool set that defines, measures and evaluates total value of given IWS acquisitions. It captures data across a spectrum of organizations to compare outputs, processes, capabilities, risks, costs, and value (i.e. comparable revenue). KVA+RO analytically quantifies uncertainty and risk elements inherent in predicting the future, includes ways to mitigate these risks through strategic options and by analytically developing and allocating budgets to optimize project portfolios. Understanding uncertainties and mitigating the potential impact of risks significantly improves the likelihood of successful acquisition decisions.

In this study, KVA+RO is used to assess the implications of OA on SA procedures onboard the AEGIS and SSDS platforms. Focusing on systems interoperability, KVA methodology is first applied to generate knowledge-based, ROI metrics on individual sub-processes and watch stations involved in track-management processes. The potential impact of OA on track management processes and sub-processes is analyzed under several scenarios: ***"To Be," "Radical 1," and "Radical 2"*** for AEGIS and SSDS. Potential investments are then evaluated for AEGIS through real options analysis, resulting in net present value (NPV) of three strategic alternatives ranging from $6.4 billion to $27.5 billion over a nine-year period and options valuations of from $23.2 to $58.8 billion.

Lessons from the "Open" Solutions Movement

Disruptive forces and accelerating shifts in technology have enabled organizations to leverage open technology platforms to achieve greater productivity and efficiency levels.

These "open" solutions offer new possibilities for solving business problems, provide business interoperability by standardization and technology transparency, and decrease time to market for key products and services. Organizations are adopting open technology platforms and open-source software for critical business needs, moving into mainstream business practices in corporations such as IBM, Google, Intel, JPMorgan Chase, Merrill Lynch and Pfizer.

One manifestation of the movement toward "openness," yet to be embraced by the Department of Defense (DoD), is the open-source software movement. Germany, Australia, the United Kingdom, Finland, Norway, Canada, China, Japan and Brazil are among the increasing number of governments embracing open-source software. Open-source software is growing at such a rate that it represents the most significant all-encompassing and long-term trend that the software industry has seen since the early 1980s, according to a recent study by International Data Corporation (IDC). IDC's survey of over 5,000 developers in 116 countries found that open source software is being used by 71% of developers in the world and is in production at 54% of their organizations.

Open-source software development site SourceForge.net reported more than 129,000 projects in 2006, up from 1,362 projects in 2000. Google's 2006 "Summer of Code" open-source initiative has 630 collaborative projects pumping more than $3 million back into the open-source community. There are now more than 55 Open-Source Initiative (OSI) certified open-source licenses available given the popularity of open-source software.[10] The success of this movement has been predicated on the ability of the multiple parties involved to easily collaborate across organizational, field-specific, and national boundaries. While this approach to software development may not directly apply to security-sensitive systems such as IWS, lessons can be learned by examining the results of this movement in the commercial world.

Collaboration is Key

As with the use of the OA technology and business model, open-source is built on the tenants of open access and collaboration. The lessons learned when "openness" is applied to system development and business models from the open-source movement is that such approaches allow access to a wider development community that can adapt, improve and fix software at a faster and more agile pace than can a proprietary vendor. Organizations are also not locked-into one vendor or product.

Google, for example, has acknowledged that the open architecture of Google Maps, allowing external developers to build applications on top of it, greatly contributed to the mapping service's functionality and diversity at a greater level than the company could have done internally (Perez, 2006, March 6).   In 2005, IBM opened access to 500 corporate software patents, forfeiting $10 million dollars in annual royalties. According to IBM, technological advances are often dependent on shared knowledge, standards and collaborative innovation (IBM, 2005, January 11).   IBM believes that by being allowed access to those patents, open-source developers will help foster continued innovation.

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[10] According to OSI, the most commonly used licenses are: Apache License, GNU General Public License (GPL), GNU Lesser General Public License (LGPL), Modified BSD (Berkeley Software Distribution) License (new BSD) and Mozilla Public License (MPL). MPL is the most widely used since 1998. A NASA license is also available (OSI, 2006).

It's critical to note that the full potential of OA and open-business model approaches cannot be achieved without a basic collaborative technology infrastructure. The ease with which all parties share ideas, compare requirements, develop solutions, test system capabilities, and finally participate jointly in deploying systems is dependent on their commitment to collaborate openly and fully with each other. This can only be facilitated, realistically and practically, through collaborative technology. Benefits from this type of approach have been previously demonstrated in shipyard planning where the use of product lifecycle management (PLM) collaborative software added tremendous potential value to the process (Komoroski, C., Housel, T., Hom, S., & Mun, J., 2006, October).

Open Architecture and the Department of Defense

Computer software plays a critical component in maintaining the nation's defenses. For example, less than 10% of its functionality was provided by software when the F-4 fighter was developed in the 1960's; at least 80% of the F/A-22's functionality is software related (GAO, 2004, March). Although the DoD spends billions of dollars to develop and maintain rights to millions of lines of code, such software cannot be accessed or modified by anyone but the original vendor because of its proprietary nature (Payton, 2006, August 14). Moreover, the DoD will spend as much as $12 billion on reworking software for major weapons acquisitions programs—30% of its estimated budget of $40 billion for research, development, testing and evaluation in Fiscal Year 2006 (Wait, 2006, July 3). Consequences resulting from the lack of OA and open business models include:

- increased development and maintenance costs for information technology;
- lock-in to obsolete proprietary technologies;
- inability to extend existing capabilities in months versus years; and
- lack of interoperability due to opacity and stove-piping of information systems. (Herz, J.C., Lucas, M., & Scott, J., 2006)

The DoD has at least 115 open-source software applications used in more than 250 applications. However, IWS software acquisitions are still made with the same industrial-age business models used to acquire ships, tanks and other physical machinery (Payton, 2006, August 14). The traditional business model of purchasing physical goods and services falls short when applied to acquiring digital assets like IWS technology. New business models are required to acquire IWS technology to wage information-age warfare requiring responsiveness and agility, according the Deputy Under Secretary of Defense for Advanced Systems and Concepts, Dr. Sue Payton (Payton, 2006, August 14). Moving to an open architecture model maximizes IT acquisitions by saving development dollars, reducing development cycles, and fostering new and innovative solutions and capabilities.

Modern, analytical tools are also necessary to deploy an open solutions business strategy. These tools must measure the operational value of a system from the warfighter's perspective, identify areas of deficiencies in capabilities, and flag areas for process improvement. Traditional measurement tools used for cost analysis cannot calculate the *total value* of a system, particularly operational value provided by specific process improvements. At the tactical level, an operator does not define capabilities merely in cost terms but also in time, efficiency and effectiveness gains like processing more targets within a given time period. Given new potential threats, such as "swarm" attacks where there may

be thousands of targets at any one time, the warfighter's perspective in developing open and agile systems is critical. Focusing on the potential cost reductions from the OA and open business models approach may lead developers and acquirers away from the real needs of the warfighter. Maintaining a focus on the potential value produced, in addition to potential cost savings, is critical to the success of OA and open business models.

KVA+RO Framework

The KVA+RO methodology provides an equal focus on the potential value and cost of new IWS systems. KVA+RO measures operating performance, cost-effectiveness, return on investments, risk, real options (capturing strategic flexibility), and analytical portfolio optimization. In this study, it was applied to the problem of finding the most promising solution for replacing aging IWS systems such as AEGIS and SSDS to support reengineered warfighting capabilities. KVA+RO analysis empowers decision-makers and supports IWS acquisition strategies by providing performance-based data and scenario analysis. Analyses like ROI on individual IWS projects and programs, as well as processes and sub-processes (e.g., track management processes in the present study) supported by IWS systems can be examined within a portfolio of acquisitions framed through the KVA+RO methodology. An overview of the framework is shown in Figure 1.

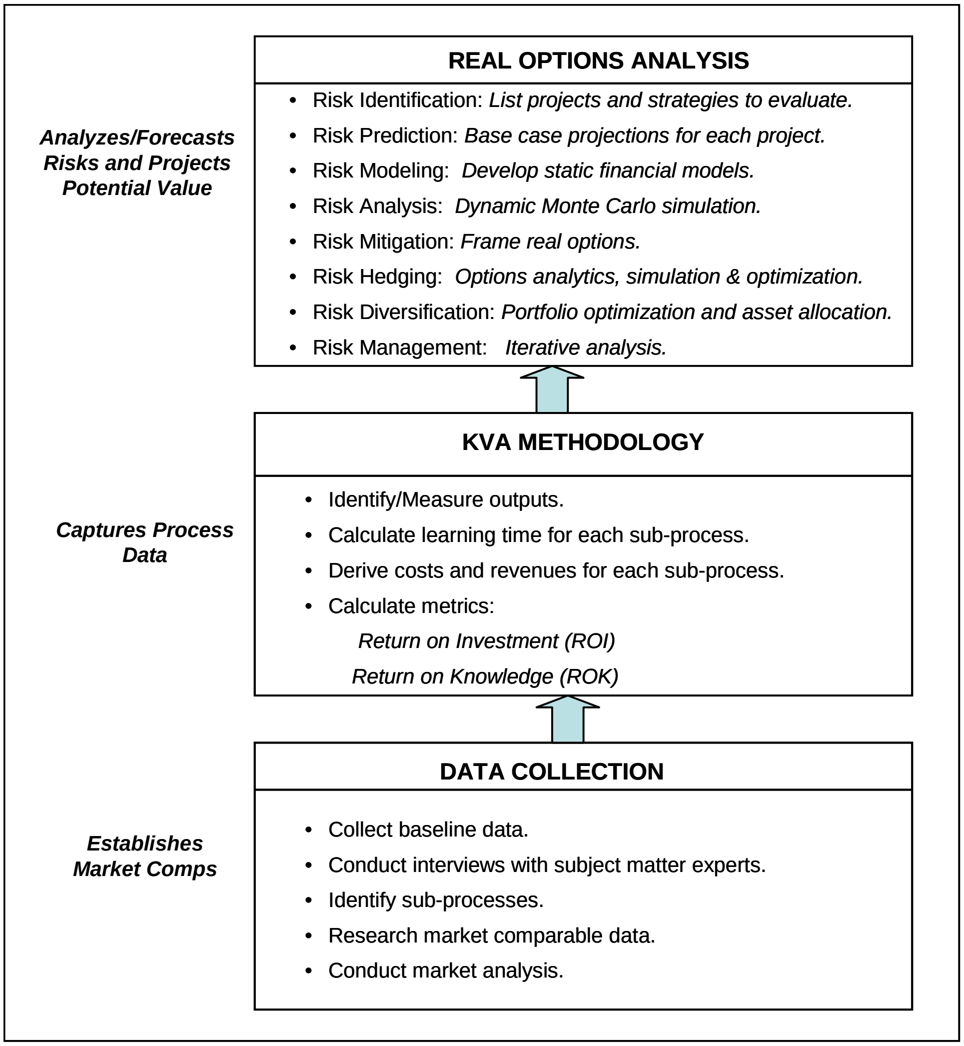

Figure 1. NPS Valuation Framework

The framework has been used in a variety of NPS analyses, including evaluating the potential impact of commercial-off-the-shelf (COTS) technology on naval maintenance/modernization processes. In the study involving one specific area of shipyard planning for maintenance alterations, cost savings were projected to exceed $40 million per year and manpower requirements drastically reduced with commercial-off–the-shelf, three-dimensional scanning/visualization technology and collaborative PLM technology (Komoroski, C., Housel, T., Hom, S., & Mun, J., 2006, October). Key components of the NPS Valuation framework are further discussed in this section.

Knowledge-based Metrics: Knowledge Value Added (KVA)

KVA measures the value provided by human capital assets and IT assets (e.g., IWS systems + human operators) by an organization, process or function at the sub-process level. It monetizes the outputs of all assets, including intangible knowledge assets. Capturing the value embedded in an organization's core processes, employees and IT enables the actual cost and revenue of a product or service to be calculated. Figure 2

identifies the types of assets used to produce output; outputs can be products or services produced by that organization.

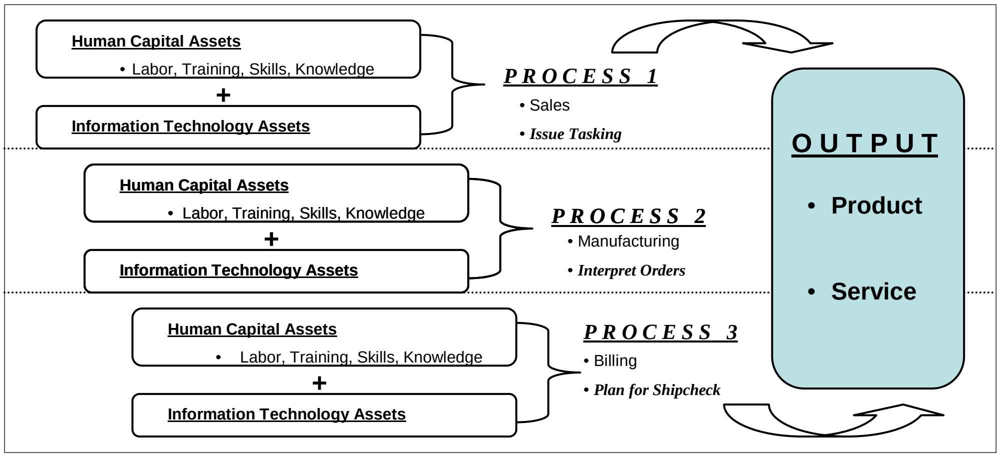

Figure 2. Measuring Output

Figure 3 shows how KVA process costing differs from traditional accounting methods.

Explains what was spent

Traditional Accounting		KVA Process Costing	
Compensation	$5,000	Review Task	$1,000
Benefits/OT	1,000	Determine Op	1,000
Supplies/Materials	2,000	Input Search Function	2,500
Rent/Leases	1,000	Search/Collection	1,000
Depreciation	1,500	Target Data Acq	1,000
Admin. And Other	900	Target Data Processing	2,000
Total	**$11,400**	Format Report	600
		Quality Control Report	700
		Transmit Report	1,600
		Total	**$11,400**

Explains how it was spent

Figure 3. Comparison of Traditional Accounting versus Process-based Costing

As seen in Table 1, total value is captured in two key metrics: ROI and ROK. While ROI is the traditional financial ratio, ROK identifies how a specific process converts existing knowledge into process outputs so decision-makers can quantify costs and measure value derived from investments in productive assets. A higher ROK signifies better utilization of knowledge assets. If IT investments, such as existing IWS systems, do not improve the ROK value of a given process, steps must be taken to improve that process's function and performance.

Metric	Description	Type	Calculation
Return on Knowledge (ROK)	Basic productivity, cash-flow ratio	Sub-corporate, process-level performance ratio	Outputs-Benefits in Common Units / Cost to Produce Output
Return on Investment (ROI)	Same as ROI at the sub-corporate, process level	Traditional investment finance ratio	(Revenue-Investment Cost) / Investment cost

Table 1. KVA Metrics

Risk Analysis: Real Options (RO)

Potential strategic investments can then be evaluated with real options analysis based on KVA data. This analysis is a robust and analytical process incorporating the risk identification (applying various sensitivity techniques), risk quantification (applying risk-based Monte Carlo simulation), risk valuation (applying real options analysis), risk mitigation (utilizing real options framing), and risk diversification (employing analytical portfolio optimization) using the *Real Options SLS* and *Risk Simulator* software programs. Figure 4 reflects the complex calculations for integrated risk analysis in KVA+RO.

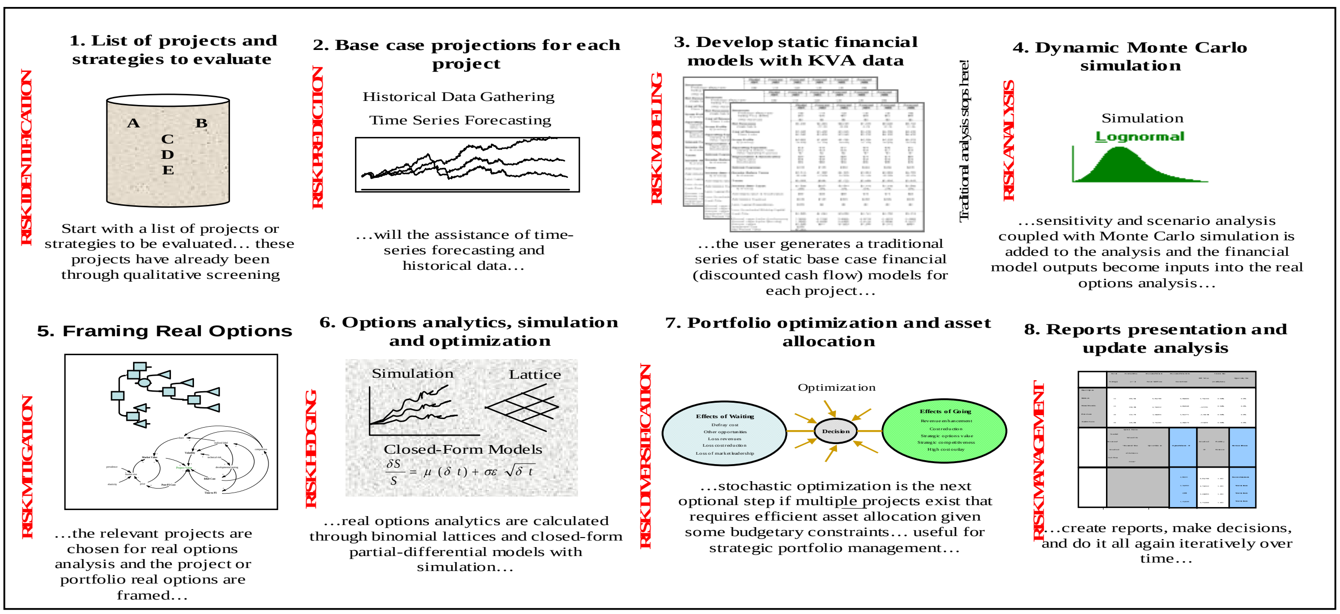

Figure 4. Integrated Risk Analysis

Beyond Concept: KVA+RO Implementations

Moving beyond a concept stage, the KVA+RO framework is being implemented in SPAWAR and in the Army Rapid Equipping Force project. KVA+RO is being used in both projects to improve processes, reduce cycle-times and costs, and increase value by allowing Navy executives to acquire intelligence systems via a portfolio approach and by

getting the Army troops in the field (i.e., Iraq and Afghanistan) what they need very quickly through new rapid acquisition processes.

Proof-of-Concept Case Study: Situational Awareness Onboard AEGIS and SSDS Platforms[11]

This proof of concept case study is designed to assist PEO IWS, Open Architecture Division, with its mandate of implementing OA in the Navy. The case is prepared from a warfighter perspective because the value of OA must be proven to the ultimate end-user. This perspective also permits a review of how OA can lead to flexible system acquisition and development to enable reengineered processes that will provide better performance in core warfighting processes such as SA.

In a multi-phased approach, KVA+RO was applied to SA-track management procedures used in the AEGIS and SSDS platforms. As illustrated in Figure 5, the total functionalities of AEGIS and SSDS systems are very broad so we focused our research on SA because it appeared to be the most promising area for upgrading and reengineering according to subject matter experts. The goals of this research were to:

- Demonstrate the efficacy of the KVA-RO framework to evaluate reengineering designs for warfighting core processes (i.e., SA-track management) in terms of the ROI and strategic option value of various OA approaches to replacing aging IWS systems.
- Determine which elements of the track management process could be reengineered using an OA approach
- Identify areas of improvement for current surface ship track-management processes using the existing two IWS systems: AEGIS and SSDS.

[11] Information collected from subject-matter experts (SMEs) from Surface Warfare Fleet and training commands at Dahlgren (AEGIS) and Wallops Island (SSDS). Information gathered from SMEs then aggregated to provide an average for each process to ensure accuracy. Additional information collected, including process flow diagrams, use-case diagrams and literature review, to develop baseline data.

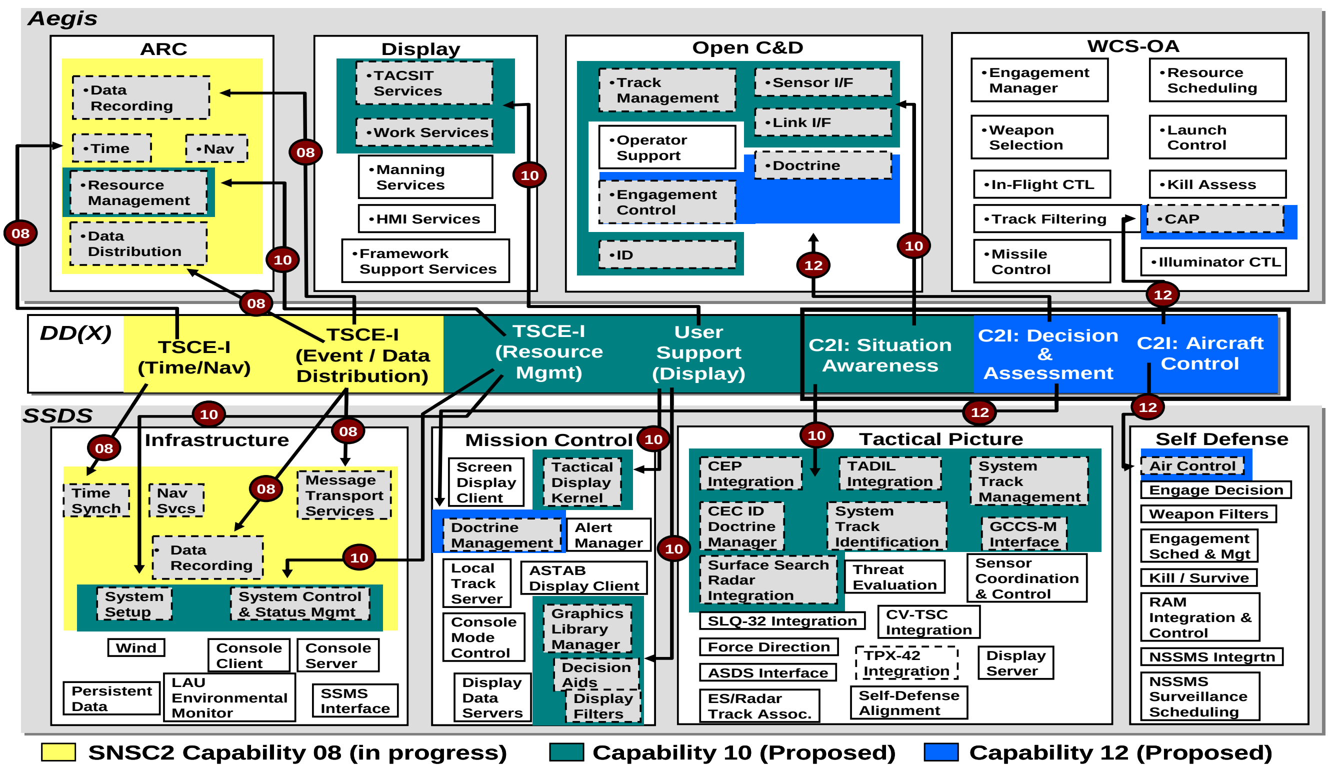

Figure 5. Planned Reuse of Aegis and SSDS in DD(X)
(MacRitchie, 2005, June 29, p. 12)

Background

In the late 1990s, the DoD articulated a vision for network-centric (or "net-centric") warfare in which networking military forces would facilitate information sharing and collaboration, leading to enhanced SA. Information superiority is vital to enhanced SA, rapid decision-making, improved efficiency, speedy execution and mission effectiveness. A high degree of interoperability is required to achieve information superiority.[12] Lack of interoperability between the services makes it difficult for the warfighter to distinguish "friend" from "foe" and to make critical decisions—potentially delaying military response times or contributing to lethal mistakes. Figure 6 shows a scenario in which a sea-based system and a land-based system are tracking aircraft and are unable to integrate their views of a battlefield.

[12] The DoD defines interoperability as the ability of systems, units, or forces to exchange data, information, materiel, and services to enable them to operate effectively together.

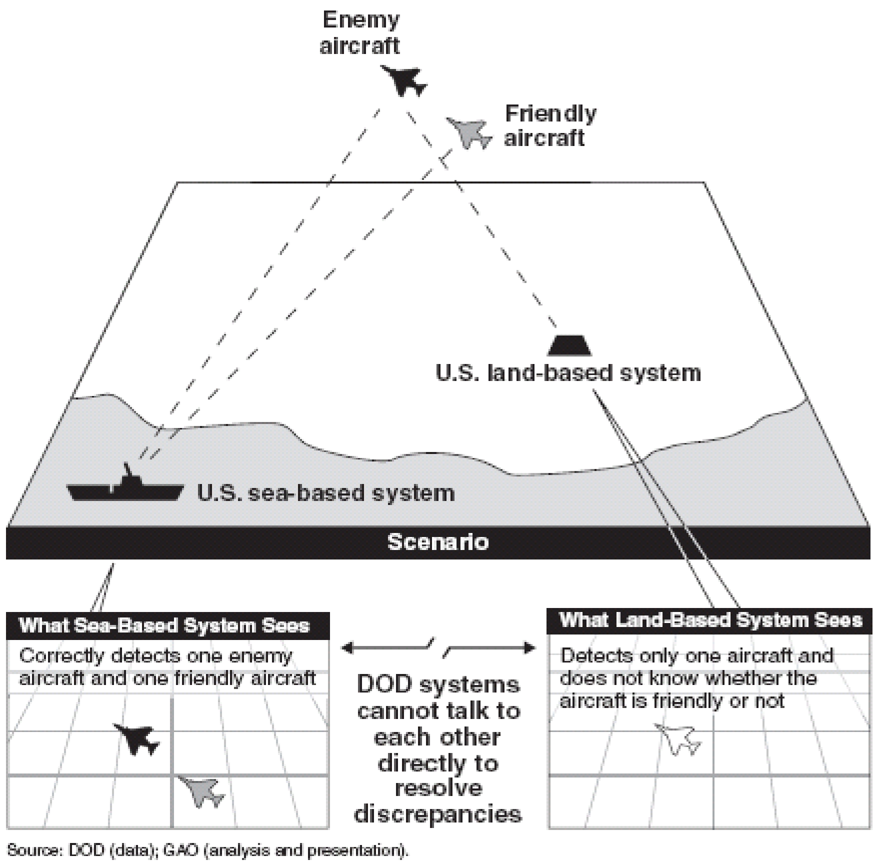

Figure 6. Scenario for Tracking Threats without Benefit of Interoperable Systems
(GAO, 2006, January, p. 6)

To achieve information superiority and enable net-centric warfare, the DoD has been developing the Global Information Grid (GIG). Interoperable systems are critical to the GIG for joint military operations and to allow users access to data on demand, to share information in real-time and to collaborate in decision-making from almost any location. Development of this capability is ultimately dependent on support from reengineered SA systems within IWS suites.

Naval Challenges

The Navy must develop architectures that meet the integration requirements for the GIG. This is a critical requirement in designing and implementing new IWS systems built within the OA framework. In addition, the Navy must resolve the following issues that are a result of legacy technology systems, such as the aging IWS systems.

- ***Limited computational and operational capability.*** Systems operating at 99% capacity in non-stressed environments.
- ***Difficulty or inability to add new warfighting missions.*** “Stove-piped” systems diminish interoperability and ability to meet national security threats.

- ***Prohibitive software maintenance costs.*** Some $3+ billion spent across Future Years Defense Plan in PEO IWS to develop and maintain computer programs. Additional testing and certification required when new capabilities added.

The Navy has historically acquired IWS systems that are proprietary in design and engineering, require unique parts, equipment, and services to support them, are supported by a limited number of suppliers, and become very expensive to maintain (Strei, 2003, April 1). Moreover, systems and/or platforms were entirely eliminated rather than upgraded or modernized because of prohibitive costs. Rapid technological obsolescence, compounded by exorbitantly escalating costs for proprietary systems are daunting challenges because design, development, and acquisition timelines can span as much as 15 years before a military platform reaches operating forces (Strei, 2003, April 1).

Naval Open Architecture and Open Business Models

OA and open-business models propel the Navy into the next era of joint interoperability while resolving legacy issues that provide new benefits, including:

- ***Lower lifecycle costs for IWS systems***. Total cost of ownership decreases due to increased maintainability, interoperability, upgradeability and use of a wider variety of vendors.

- ***Better performing systems.*** Ability to rapidly upgrade hardware and software with the latest technology enables greater capabilities, efficiencies and interoperability to enable reengineered warfighting processes.

- ***Improved interoperability for joint warfighting.*** Software reuse and modularity facilitates interoperability between systems that use an open architecture framework.

- ***Facilitating competition and increasing cooperation between commercial and military electronics industries.*** Moving away from proprietary systems enables a broader range of ideas and technological solutions.

Guiding principles behind Naval OA are modularity, reusability, interoperability, lifecycle affordability and collaboration and competition. In adopting an open, OA strategy based on commercially available, non-proprietary information technology (IT) standards, interfaces and formats, the Navy will need to increase collaboration (e.g., supported by readily available collaborative product lifecycle management technology) to spur competition and fuel innovation in the acquisition lifecycle.

Ease of collaboration is critical to Naval OA to ensure that multiple vendors compete, including the smaller, more nimble companies. Collaboration also provides the infrastructure necessary to facilitate all parties sharing critical requirements and performance information to reduce system modification, re-fresh or replacement cycle-times. As such, collaborative capabilities will facilitate moving OA beyond a purely technical focus to a more encompassing open-business model, one advocated by CNO Admiral Mullen. As noted earlier, Admiral Mullen’s vision for open architecture isn’t limited to systems built to a set of open standards, but focuses on open-business models tapping into a multiple-developer network to deliver innovative, cost-effective and rapid, spiral acquisition capabilities to the Navy.

Migrating to an OA environment has been slow, however, despite the Navy's early adoption of open source strategies. Encouraged by the cost-effective advantages gained through the Acoustic Rapid commercial off –the-shelf Insertion/Advanced Processor Build (ARCI/APB) program, Admiral Mullen noted in a recent memo his disappointment with the slow pace of adoption and advocated rapid transition to the open-business model (Fein, 2006, September 11).

SA: Track-management Processes

Track management, a fundamental capability inherent to all IWS SA capabilities for surface ships, is the process by which friendly and enemy forces are detected, identified, monitored, updated and communicated throughout the area of operations (AOR). The track management process within a Combat Information Center (CIC) is very complex, sophisticated and involves multiple watch stations and technological systems. AEGIS and SSDS have different SA procedures and policies, and track-management functions within the CIC. Although variations exist in track-management processes, watch stations are fairly consistent on both AEGIS and SSDS ships. Figure 7 is a generalized organizational chart of CIC personnel directly involved in track-management processes.[13]

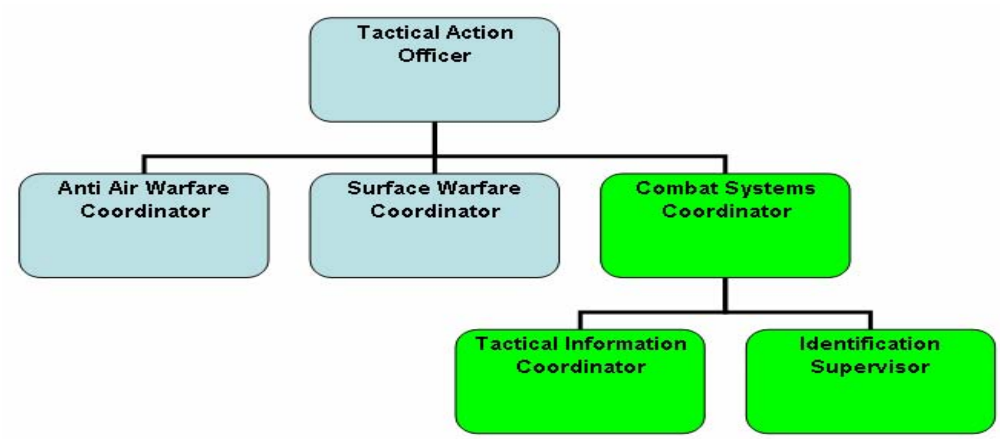

Figure 7. CIC Organizational Chart

Track-management processes entail various sub-processes, as seen in Figure 8.[14] This graphic is an aggregated view for both AEGIS and SSDS platforms consisting of four principal processes and 17 sub-processes.

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13 Although watch stations talk to specific tasks and responsibilities, in an actual CIC, all personnel listed can be actively involved in any, or all, aspects of track management (correlation, identification, tracking, and relaying).

14 Figure derived from numerous SMEs from AEGIS and SSDS communities. While sub-processes may differ from ship to ship, SMEs concluded that the four primary processes reflect track management procedures conducted within a CIC. SMEs agreed that the 17 sub-processes shown reflected individual tasks appropriate for this limited research. SMEs also concluded that there is no definitive sequential order in which specific tasks occur; however, the figure provides a potential sequence.

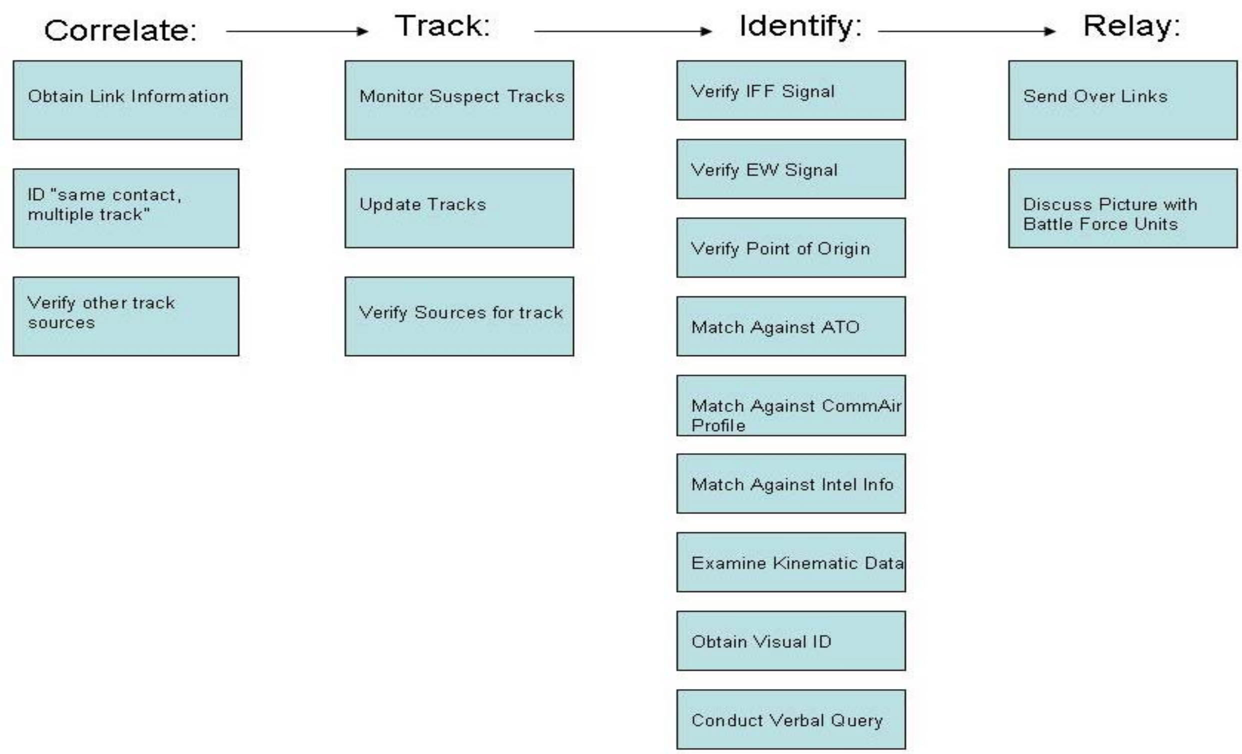

Figure 8. Track Management Sub-processes

Case Study Results: Potential Impact of OA

The potential impact of OA on AEGIS and SSDS platforms was calculated through KVA+RO in a multi-phased approach. In addition, KVA data estimates and real options models were based on the assumption that functional upgrades would primarily be in the SA area with the remaining modules providing at least the same capabilities as the current AEGIS IWS system.

KVA methodology was first applied to derive potential benefits in SA processes within AEGIS and SSDS-class ships (i.e., 84 Destroyers and Cruisers). Track-management sub-processes by process category (and by watch station in Appendix B) were evaluated under four improvement scenarios (*"As Is," "To Be," "Radical 1," and "Radical 2"*). The following assumptions were used to calculate the data:

- Integration with middleware until Category 3 Open Architecture Computing Environment (OACE) level has been reached for systems being evaluated
- Use of OA approach to developing the IWS systems and use of Commercial-off-the-shelf (COTS) equipment

Steps in calculating KVA data were:

1. Identify core processes and sub-processes.
2. Establish common units and level of complexity to measure learning time.
3. Calculate learning time (i.e., knowledge surrogate) to execute each sub-process.
4. Designate sampling time period long enough to capture representative sample of the core processes' final product or services output.
5. Multiply learning time for each sub-process by number of times sub-process executes during sample period.
6. Calculate cost to execute knowledge (learning time and process instructions) to determine process costs.
7. Calculate ROK (ROK= Revenue/Cost) and ROI (ROK= Revenue-Cost/Cost).

During Phase 2, real options analysis focused on the options for improving (*Leave and Layer* option) or replacing (*Retrofitting* option) the AEGIS IWS system. The option to continue with the current proprietary systems approach was provided as a baseline for comparison purposes. Future research would allow us to examine all AEGIS modules for potential upgrading and would likely result in even higher ROI estimates as well as real options valuations.

KVA Results: ROK and ROI

ROK and ROI values provide insights into sub-processes that could be reengineered to achieve maximum operational efficiency. Aggregated results for AEGIS and SSDS are shown Figures 9 and 10. The “As Is” provides a baseline ROI/ROK performance measure for comparison of the three process reengineering designs. The three redesigns essentially represent the effects of increasing levels of automation in the track management process.

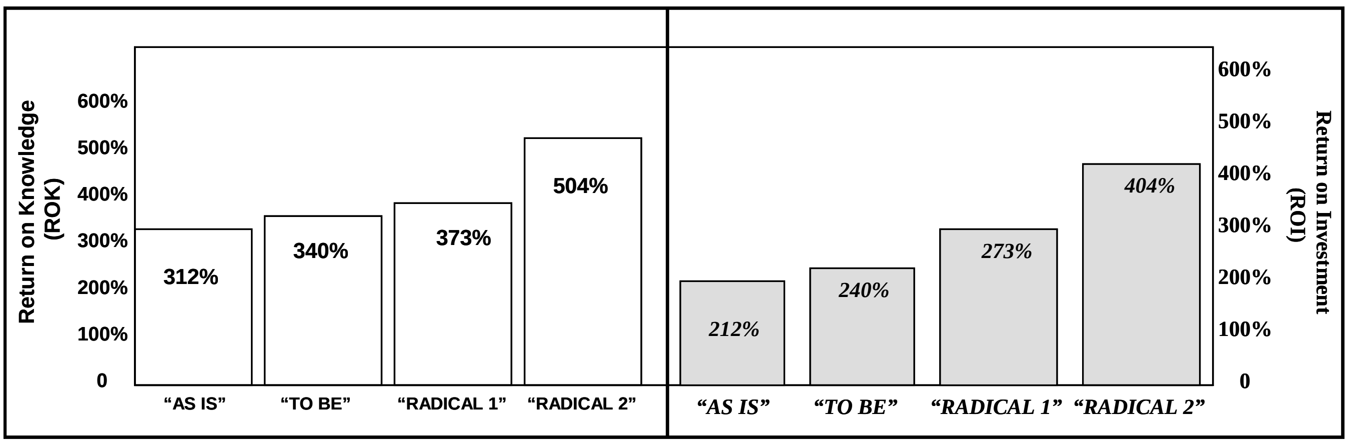

Figure 9. KVA Results: ROK and ROI Estimates

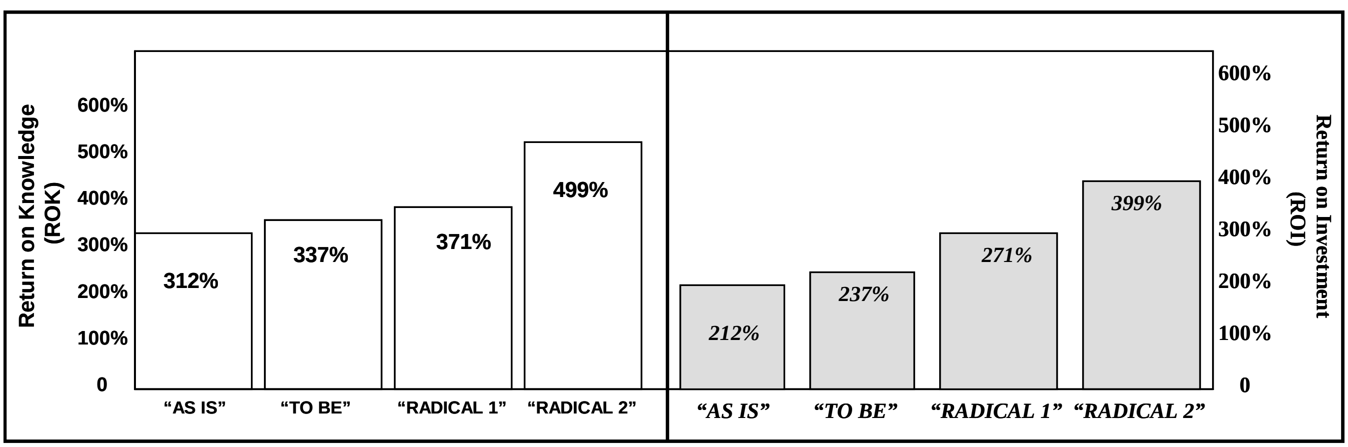

Figure 10. KVA Results: ROK and ROI Estimates

OA has the potential to provide these operational performance improvement benefits: decreased training time for operators of systems, decreased “touch time” on processes by replacing manual processes with new automated capabilities, and increased efficiency through seamless integration of multiple system components. As shown in Table 2 below, the cumulative impact of OA on the track-management processes results in significant improvement in three of four areas.

	"To Be"	"Radical 1"	"Radical 2"	Cumulative Impact
CORRELATE		X	x	x
TRACK	X	X	x	x
IDENTIFY	X	x	X	x
RELAY				

Table 2. Process Reengineering Impacts: Process Level and Cumulative

Tables 3 through 6 are ROK and ROI results by core processes and sub-processes for AEGIS and SSDS. The ROI estimates demonstrate that as various system functionalities of the existing track-management process are upgraded, a corresponding performance improvement is derived in those areas. This more detailed analysis suggests where OA based system upgrades should be applied to achieve the best results. For example, the core process of correlate and identify have the greatest potential to benefit from an OA approach to system development. These estimates also provide the basis for the real options analysis projections staged over a 9-year period.

	AS IS	TO BE	RAD 1	RAD 2
CORRELATE				
Obtain Link Information	3521%	3407%	3163%	2733%
Identify "Same Contact, Multiple Track"	9%	9%	2161%	1856%
Verify Other Track Sources	5%	5%	5%	4%
Correlate sub-total	***1284%***	***1241%***	***1606%***	***1396%***
TRACK				
Monitor Suspect Tracks	2%	1%	1%	1%
Update Tracks	3%	3%	461%	410%
Update GCCS-M	3%	191%	184%	169%
Track sub-total	***2%***	***6%***	***42%***	***36%***
IDENTIFY				
Verify IFF signal	902%	869%	806%	707%
Verify EW emissions	9%	9%	8%	609%
Verify Point of Origin	2%	4221%	3921%	3432%
Match Against ATO	2%	4306%	3990%	3482%
Match Against CommAir Profile	963%	935%	863%	743%
Match Against Intel Information	3%	3%	3%	3914%
Examine Kinematic Data	4%	4%	3%	3%
Obtain Visual ID	0%	0%	0%	0%
Conduct Verbal Query	1%	1%	1%	1%
Identify sub-total	***108%***	***160%***	***150%***	***426%***
RELAY				
Send Over Links	13%	12%	11%	10%
Discuss Picture with Battle Force Units	2%	1%	1%	1%
Relay sub-total	***3%***	***2%***	***2%***	***1%***
TOTALS	**312%**	**340%**	**373%**	**504%**

Table 3. Detailed ROK Estimates for AEGIS

	AS IS	TO BE	RAD 1	RAD 2
CORRELATE				
Obtain Link Information	3493%	3380%	3126%	2698%
Identify "Same Contact, Multiple Track"	9%	9%	2630%	2258%
Verify Other Track Sources	5%	5%	4%	4%
Correlate sub-total	***1274%***	***1231%***	***1612%***	***1401%***
TRACK				
Monitor Suspect Tracks	2%	1%	1%	1%
Update Tracks	4%	3%	646%	575%
Update GCCS-M	2%	114%	110%	101%
Track sub-total	***2%***	***4%***	***47%***	***40%***
IDENTIFY				
Verify IFF signal	890%	857%	792%	695%
Verify EW emissions	10%	9%	9%	574%
Verify Point of Origin	2%	3789%	3505%	3067%
Match Against ATO	2%	3913%	3610%	3149%
Match Against CommAir Profile	1026%	996%	916%	788%
Match Against Intel Information	3%	3%	3%	3788%
Examine Kinematic Data	4%	4%	4%	4%
Obtain Visual ID	0%	0%	0%	0%
Conduct Verbal Query	1%	1%	1%	1%
Identify sub-total	***112%***	***159%***	***148%***	***416%***
RELAY				
Send Over Links	18%	17%	16%	14%
Discuss Picture with Battle Force Units	1%	1%	1%	1%
Relay sub-total	***3%***	***2%***	***2%***	***2%***
Totals	**312%**	**337%**	**371%**	**499%**

Table 4. Detailed ROK Estimates for SSDS

	AS IS	TO BE	RAD 1	RAD 2
CORRELATE				
Obtain Link Information	3421%	3307%	3063%	2633%
Identify "Same Contact, Multiple Track"	-91%	-91%	2061%	1756%
Verify Other Track Sources	-95%	-95%	-95%	-96%
Correlate sub-total	***1184%***	***1141%***	***1506%***	***1296%***
TRACK				
Monitor Suspect Tracks	-98%	-99%	-99%	-99%
Update Tracks	-97%	-97%	361%	310%
Update GCCS-M	-97%	91%	84%	69%
Track sub-total	***-98%***	***-94%***	***-58%***	***-64%***
IDENTIFY				
Verify IFF signal	802%	769%	706%	607%
Verify EW emissions	-91%	-91%	-92%	509%
Verify Point of Origin	-98%	4121%	3821%	3332%
Match Against ATO	-98%	4206%	3890%	3382%
Match Against CommAir Profile	863%	835%	763%	643%
Match Against Intel Information	-97%	-97%	-97%	3814%
Examine Kinematic Data	-96%	-96%	-97%	-97%
Obtain Visual ID	-100%	-100%	-100%	-100%
Conduct Verbal Query	-99%	-99%	-99%	-99%
Identify sub-total	***8%***	***60%***	***50%***	***326%***
RELAY				
Send Over Links	-87%	-88%	-89%	-90%
Discuss Picture with Battle Force Units	-98%	-99%	-99%	-99%
Relay sub-total	***-97%***	***-98%***	***-98%***	***-99%***
Totals	**212%**	**240%**	**273%**	**404%**

Table 5. Detailed ROI Estimates for AEGIS

	AS IS	TO BE	RAD 1	RAD 2
CORRELATE				
Obtain Link Information	3393%	3280%	3026%	2598%
Identify "Same Contact, Multiple Track"	-91%	-91%	2530%	2158%
Verify Other Track Sources	-95%	-95%	-96%	-96%
Correlate sub-total	***1174%***	***1131%***	***1512%***	***1301%***
TRACK				
Monitor Suspect Tracks	-98%	-99%	-99%	-99%
Update Tracks	-96%	-97%	546%	475%
Update GCCS-M	-98%	14%	10%	1%
Track sub-total	***-98%***	***-96%***	***-53%***	***-60%***
IDENTIFY				
Verify IFF signal	790%	757%	692%	595%
Verify EW emissions	-90%	-91%	-91%	474%
Verify Point of Origin	-98%	3689%	3405%	2967%
Match Against ATO	-98%	3813%	3510%	3049%
Match Against CommAir Profile	926%	896%	816%	688%
Match Against Intel Information	-97%	-97%	-97%	3688%
Examine Kinematic Data	-96%	-96%	-96%	-96%
Obtain Visual ID	-100%	-100%	-100%	-100%
Conduct Verbal Query	-99%	-99%	-99%	-99%
Identify sub-total	***12%***	***59%***	***48%***	***316%***
RELAY				
Send Over Links	-82%	-83%	-84%	-86%
Discuss Picture with Battle Force Units	-99%	-99%	-99%	-99%
Relay sub-total	***-97%***	***-98%***	***-98%***	***-98%***
Totals	**212%**	**237%**	**271%**	**399%**

Table 6. Detailed ROI Estimates for SSDS

Table 7 summarizes how OA could specifically impact the sub-processes deriving most significant improvements: "Identify 'Same Contact, Multiple Track'," "Update GCCS-M," "Update Track," "Verify Point of Origin," "Match against ATO," "Verify EW Emissions" and "Match Against Intel Information." Each watch station at the CIC was affected (see Appendix B).

PROCESS	SUB-PROCESS	COMMENTS POTENTIAL IMPACT OF OA
CORRELATE	**"Identify 'Same Contact, Multiple Track'"**	• Reduces reliance on manual identification of multiple tracks and updating current tracks. • Automatically corrects anomaly of multiple tracks per target and update tracks. Only brief confirmation by the watch station operator necessary.
TRACK	**"Update GCCS-M"**	• Enhances operational value of systems through reduced time, manpower and training required to conduct process.
TRACK	**"Update Track"**	• Reduces reliance on manual identification of multiple tracks and updating current tracks. • Automatically corrects multiple tracks per target anomaly and update tracks, resulting in brief confirmation by watch station operator.
IDENTIFY	**"Verify Point of Origin"**	• Enables greater sensor and data integration, providing enhanced correlation in pinpointing origin of aircraft or ship. • Queries point of origin for friendly force contacts from an open GCCS-M system, and interrogates ATO neutral-force contacts from host nation airports (assuming data format standardized and provided by host nations.). • Facilitates interfaces to other systems to provide automated query for point of origin. • Frees watch standers to perform other tasks while providing faster data flow.
IDENTIFY	**"Match Against ATO"**	• Integrates info provided in ATO into the AEGIS and SSDS platforms, greatly reducing manpower requirements.
IDENTIFY	**"Verify EW Emissions"**	• Facilitates COTS-based environment for easier upgrades to accommodate greater processor speeds. • Enhances CIC efficiency through more timely SA. • Frees operators to perform other tasks.
IDENTIFY	**"Match Against Intel Information"**	• Streamlines sub-process with automatic updates requiring merely manual confirmation.

Table 7. Potential Impact of OA at Sub-process Levels

Value-risk Analysis: Strategic *Real Options* Analysis

Real options analysis was performed to determine the prospective value of alternative COAs for upgrading the AEGIS IWS in track management over a nine-year period with KVA data inputs. In all new options for IWS deployment, it was assumed that a collaborative technology infrastructure was present to facilitate the use of the OA system and open-business model approaches.[15]

Figure 11 illustrates the three main strategies laid out as a real options map. Strategy A is do nothing, leaving everything "As Is" with the ability to retire ships and their AEGIS systems within 10 years. Strategy B is the "DDX Open Architecture" (retrofit) option with new development within the first three years at a cost of $8 billion. Under this strategic path, follow-up is required—with retrofitting costing an additional $16 billion within 6 years

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[15] Estimates are based on historical data and additional information provided by SMEs. We have attempted to be as conservative as possible and have assumed very high potential volatility in both of the new IWS development options. Access to more precise performance data will help resolve uncertainties and risks over time.

after first-phased new development has been completed. Strategy C looks at the "Leave and Layer" option with a three-phased sequential compound option of "To Be," " Radical 1,", and "Radical 2" implementation within 9 years.

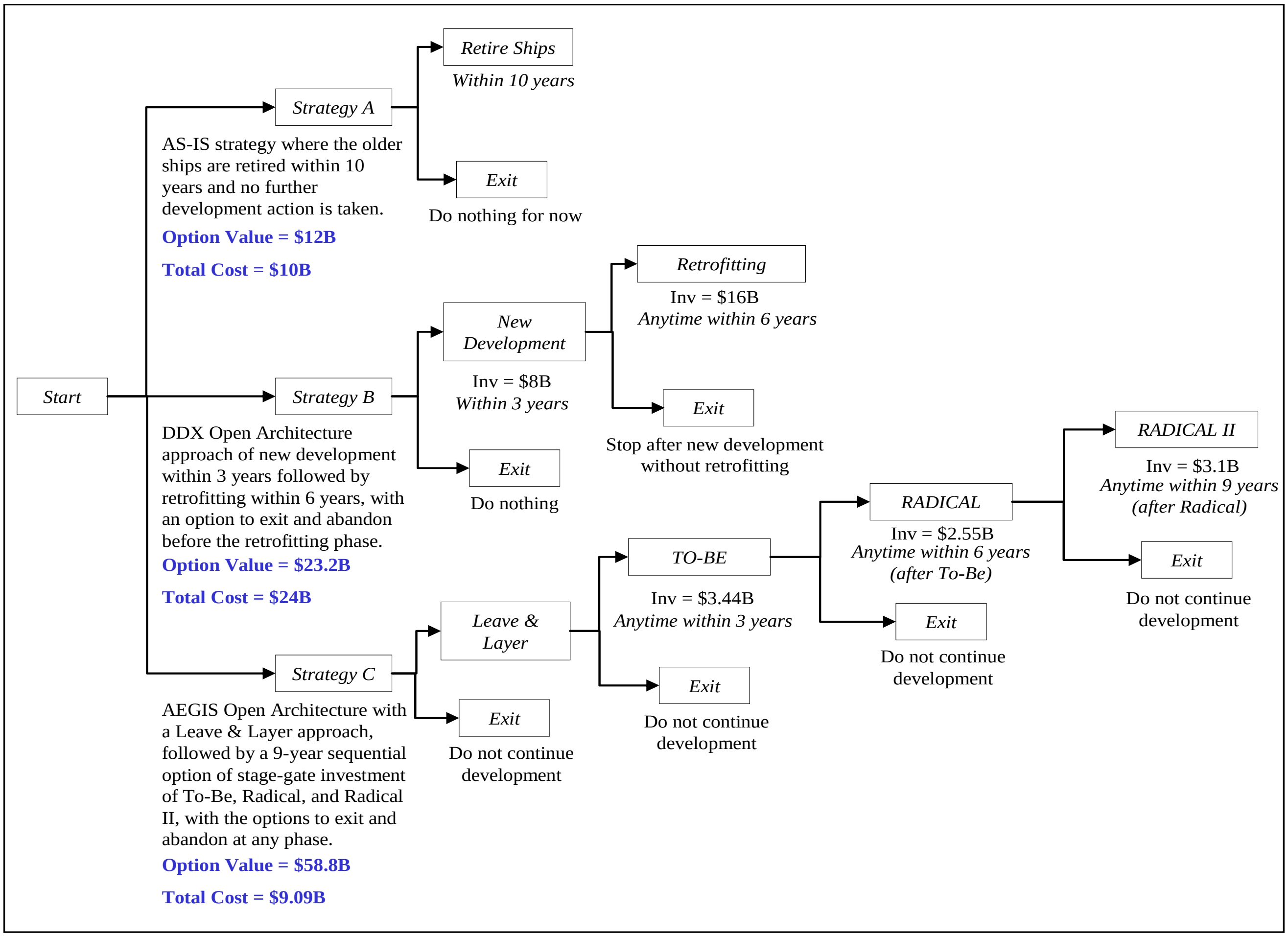


Figure 11. Strategic Real Options Map

Strategy C is the option with the greatest potential value. As seen in Table 8 below, Strategy C provides 4.9 times the risk adjusted return of the "As Is" strategy versus Strategy B at 1.9 times the return. Strategy C's incremental approach offers the lowest risk and numerous benefits, including less disruption to the rest of system and deriving benefits faster. It is the lowest total cost alternative with costs spread over a nine-year period, yet the program reaps incremental benefits from various functionality improvements throughout that time. This strategy provides the highest NPV.

	Strategy A	Strategy B	Strategy C
STRATEGIC OPTION	"As Is"	DDX OA "Develop and Retrofit"	AEGIS OA "Leave & Layer"
Net Present Value	$12B	$6.38B	$27.52B

Volatility	0%	80.5%	86.3%
Real Options Value	$12B	$23.155B	$58.84B
Strategic Real Options-based Return on Investment	N/A	72.36%	224.75%
Total Cost	$10B	$24B	$9.09B
Strategic Real Options-based Relative Return Ratio	1.0	1.9	4.9

Notes:

(1) The volatility measure quantifies uncertainty and risk levels in the strategy and calibrates them to account for the time required to complete the entire strategy.

(2) Strategic real options values are also computed, accounting for value of open architecture as laid out in the phased-gate development process.

(3) Strategic real options-based return on investment looks at real options valuation results and computes ROI based on the option values and implementation of costs each phase. The higher this ROI value, the more strategic and valuable or profitable a project.

Table 8. Real Options Valuation Results: Strategies A-C

"Leave and Layer" allows organizations to benefit from incremental adoption. Rather that executing a plan that requires everything to be accomplished at once, "leave and layer" enables existing systems to be reused successfully. NAVFAC successfully adopted the approach to provide a more efficient, lower cost contract management solution. NAVFAC architected a technology platform to allow it to build a layer of Web-based collaborative project management tools, while leveraging existing financial, HR, and scheduling systems. A number of applications were developed, including the collaborative eProjects application with a budget of $350,000 and completion in 10 months (Oracle, 2004). eProjects provides one-click schedule and cost status. Another application, eContracts, automates nearly 200 redundant screens per contract action.

In our analysis, Strategy B has the highest cost due to high up-front costs required to build the system within the first five years without deriving any benefits from the new system during that time. Both strategies B and C require the use of collaborative infrastructure to enable the open business model that would be most likely to produce these real options values. Strategy C, in fact, relies most heavily on collaboration to enable the kinds of benefits in rapid, spiral acquisition with greater competition and innovation from smaller players.

Summary

IWS systems that were developed in a closed, proprietary model have performed well and provide substantial returns. However, a new paradigm is required to maintain military superiority and wage information-age warfare. Through open-system development and open-business models, benefits such as reusable code, lower maintenance-upgrade costs, and greater vendor flexibility in supporting system modules could be derived. Moreover, the Navy can leverage new technology by quickly adopting it to military needs.

Significant investments are required for the infrastructure necessary to enable all parties (acquirers, users, developers) to collaborate easily and effectively in the new open-business model. Analytical tools are also required to track performance of the multiple parties involved in the development, acquisition and use of new system capabilities, in conjunction with the ability to adjust options models as uncertainties and risks are resolved over time. Performance measurement systems (i.e. KVA performance accounting software)

and predictive, forecasting software programs plus risk certification training provide additional analytic support to achieve IWS systems acquisition strategies.

Appendix A. Case Study Notes

Methodology

Case Study Approach

The learning-time approach to KVA is used to conduct sub-process scenario analyses of “As Is,” “Radical 1,” and “Radical 2.” Core elements of KVA (such as “time-to-learn,” “number of personnel involved,” and “times fired”) produce a ratio of knowledge capital (ROK) resident in each process. ROK derives a common unit of measurement for each sub-process within the track-management process.

Data Collection

Collecting data to conduct KVA analysis was difficult due to the complex nature of track-management procedures in the CIC. Outputs, learning time and touch time of the many sub-processes that comprise the entire procedure are not generally collected or retained. Also, training times and required OJT are targeted at specific watch stations rather than at specific processes within the Navy. Consequently, data was derived through numerous interviews with SMEs and review of Personal Qualification Standards (PQS). Multiple SMEs were contacted to collect an aggregated sample.

“To Be” Data

Analysis based of situations that SMEs identified as optimal areas where open architecture could provide value to the operator. In addition, technical and legal issues of the “To Be” scenario were not assessed.

Discussion of Basic Assumptions Used in Calculations

Cost and Revenue Data

- Calculations based on a ship performing SA and track management processes 24 hours a day, 7 days a week operating an average of 35 weeks per year.

- Net present value in total revenue estimates is based on a 30-year system-life expectancy of ship.

- A contractor-margin approach was used to generate surrogate comparable revenue estimates. Contractor margin is defined as the amount market place would pay a group of contractors, with levels of knowledge comparable to the existing team, to perform the activities of the track management team (e.g the margin over current Navy costs for the track management team). This market-comps approach was used because there were no commercial processes directly comparable to track management activities in the military. Future studies would allow a wider range of potential commercially comparable processes to be assessed for comparability/fit revenue estimates.

- Surrogate comparable revenue estimates are conservative given that revenue calculations were based on six people in the SA, track-management process. In reality, more people may be involved in this process.

New Development/Retrofitting DD(x)

- PV Asset New Development: Calculated by translating hourly revenue of the combined SSDS/AEGIS “AS-IS” estimates to yearly revenue, calculating the present value of the yearly revenue based on a 30-year lifecycle, and assuming retrofitting on all current 84 Aegis destroyers/cruisers.

- PV Asses Retrofitting: Calculated by translating hourly revenue of the combined SSDS/AEGIS RADICAL estimates to yearly revenue, calculating the present value of the yearly revenue based on a 30-year lifecycle, and assuming retrofitting on all current 84 AEGIS destroyers/cruisers.

- Cost to Execute: Based on estimation from SMEs and refining based on historical costs of AEGIS.*

- Operations/Maintenance Costs: Based on historical costs of AEGIS and scaled down to account for open architecture.

- Timing: Based on estimates by SMEs.

Leave and Layer/AEGIS

- PV Asset: Calculated by translating hourly revenue of the combined SSDS/AEGIS estimates to yearly revenue, calculating the present value of the yearly revenue based on a 30-year lifecycle, and taking into account current placement on 84 destroyers/cruisers.

- Cost to Execute: Based on $5 billion development costs and scaled according to increases in knowledge units.

- Operations/Maintenance Costs: Based on historical costs of AEGIS and scaled down to account for open architecture.

- Timing: Based on estimates by SMEs.

Use of Data in Case Study Calculation

Item	Definition	Comments
No. of Personnel	Sailors and officers involved in performing sub-process.	—
Actions per Hour	Times each sub-process acted upon by watch-stander.	• Actions predicated on amount of contacts (air and surface) encountered during a typical hour within the CIC. Each contact must be acted upon. • Estimates based on a typical, six-month deployment. • Number of contacts based on average of open-ocean transit and operations in littorals.
Actual Work Time (AWT)	Specific amount of time required to accomplish action every time sub-process acted upon.	• Data captured in hourly units. • Although actions require only seconds, category captures data in hours to maintain continuity of units of time throughout analysis.
Total Work Time	Total amount of time each sub-process acted upon within an hour.	• *Formula= "AWT" x "Actions per Hour"* • Analysis in hourly units: when "Total Work Time" for each of sub-processes added together for each of the watch stations, total aggregate should remain below 1.0. If total exceeded 1.0, calculations are incorrect.
Actual Learning Time (ALT)	Total amount of time required to learn given sub-process.	• Learning time can be an aggregate of formal schools, distance learning, on-the-job training (OTJ) or any other training experience that falls under definition of "learning." • For this case, comprised of formal school training and OJT provided aboard ship. • Basic assumptions to ensure consistent estimates from SMEs: **a. Officer-SSDS** Individual completing initial officer training with no prior SSDS platform experience. It was also necessary to determine formal schools represented by this category. While each school's duration is considerably longer than hours represented in the "ALT" category, estimates based on the aggregated amount of time devoted to teaching given sub-process from each school: SSDS Basic Operator Course of Instruction, SSDS Advanced Operator Course of Instruction, and SSDS Warfare Operator Course of Instruction. **b. Officer-AEGIS** Individual completing officer training with no prior AEGIS platform experience. It was also necessary to determine formal schools represented by this category. While each school's duration is considerably longer than the hours represented in the "ALT" category, estimates based on aggregated amount of time devoted to teaching the given sub-process from each school: AEGIS Training Course, SWOS TAO School, and TAO Simulator Training. **c. Enlisted-SSDS** Individual completed boot camp with no prior SSDS platform experience. It was also necessary to determine formal schools represented by this category. While each school's duration considerably longer than hours represented in the "ALT" category, estimates determined based on aggregated amount of time devoted to teaching the given sub-process from each school: OS "A" School, SSDS Basic Operator Course of Instruction, SSDS Advanced Operator Course of Instruction, and SSDS Warfare Operator Course of Instruction (E5 and above). **d. Enlisted-AEGIS** Individual completed boot camp with no prior AEGIS platform experience. It was also necessary to determine formal schools represented by this category. While each school's duration is considerably longer than hours represented in the "ALT" category, estimates based on aggregated amount of time that devoted to teaching given sub-process from each school: OS "A" School and AEGIS Console Operator Course.
Rank Order	An ordinal ranking of sub-processes provides a means to ensure the "ALT" estimates are reliable and as accurate as possible.	• Allowing SMEs to rank/order each of the sub-processes (1 being the least complex), outside the context of units of time, facilitates a mathematical correlation achieved between "Rank Order" and "ALT" categories. • If correlation is .80 or higher, "ALT" numbers can be considered an accurate reflection of the sub–process's complexity. • If correlation is below .80, "ALT" estimates should be closely scrutinized and possibly reevaluated after providing a better explanation of the "ALT" components to the SMEs.
Percent	Percent of automation for	• Captures knowledge embedded within the IT so that it can be accounted for in later calculations. Automation is defined as the amount of the sub-process that is

Information Technology (%IT)	each sub-process.	performed by information technology systems and does not require the actions of an operator. • Each sub-process is represented by a percentage between 0 and 100. A number of 100% indicates sub-process is completely automated and does not require a watch stander to accomplish any portion of the task. • If number is 0%, no automation exists, and the watch-stander completes the entire sub-process manually. Numbers falling between extremes are estimates based on SME observations and experience.
Total Learning Time (TLT)	**Provides total time required to learn sub-process, including that learning time which is resident within the IT system.**	• Determined by "Actual Learning Time" by the "Percent Information Technology" category. • *Formula = ALT/(1-%IT).* • For instance: If it takes 2 hours to learn a system that is 50% automated, then the total learning time for that system (to include the learning time that is embedded in the system itself) would be 4 hours.
Numerator	**Revenue generated by knowledge required to perform sub-process.**	• Revenue allocated to the amount of knowledge; amount of knowledge resident in sub-process. • Formula= *"Number of Personnel" x "Actions per Hour" x "Total Learning Time"*
Denominator	**Cost associated with producing sub-process output.**	o *Formula = "Number of Personnel" X "Actions per Hour" X "Actual Work Time"*
Return on Knowledge (ROK)	Represents how well knowledge assets in organization are distributed based upon cost and value each provides.	• With every sub-process, there is a cost and revenue (or value) associated with generating an output. While these costs and values are captured in the "Numerator" and "Denominator" categories, there needs to be a way to quantify the knowledge embedded within an IT system. • ROK's can be compared within a process to help determine if knowledge assets are being used in an efficient manner; if automation could be inserted to improve outputs; and if processes should be changed to promote efficiencies. • A low ROK does not automatically assume a process is inefficient or in need of automation, but rather is an indicator that a sub-process may need further analysis to determine if it is using its knowledge assets in an efficient manner.

Variability Report

Average Work Time: 5% Variability—The time it takes to complete each action is relatively stable with little or no variability.

Average Learning Time: 5% Variability—Estimates regarding average learning time are based on the time it takes an average person to learn each task, hence, low variability.

Price: Assume 60% of the time the position is priced at the average of the low and high estimates. The remaining time is split 20-20 between the low and high values. A custom distribution is utilized to fulfill these requirements.

Watch Station	Cost Range (per hour)
Tactical Action Officer (TAO)	$85 to $105, $80.00 to $110.00
Anti-air Warfare Coordinator (AAWC)	$75 to $90, $72.00 to $92.00
Surface Warfare Coordinator (SUWC)	$75 to $90, $72.00 to $92.00
Combat Systems Coordinator (CSC)	$78 to $95, $69.00 to $89.00
Tactical Information Coordinator (TIC)	$70 to $80, $65.00 to $85.00
Identification Supervisor (IDS)	$70 to $80, $63.00 to $83.00

Note: Prices provided by commercial vendors.

Cost: Assumes 60% of the time the position is filled by a person with the assumed pay grade. The remaining time is split 20-20%

between a person with one rank higher and one rank lower.[16] A custom distribution is utilized to fulfill these requirements.

Watch Station	Years of Service	Cost
Tactical Action Officer (TAO): (0-5)	between 10-18	$38
Anti-Air Warfare Coordinator (AAWC): (0-4)	between 8-16	$34
Surface Warfare Coordinator (SUWC): (0-3)	between 6-14	$30
Combat Systems Coordinator (CSC): (E-8)	between 10-18	$27
Tactical Information Coordinator (TIC): (E-6)	between 4-14	$17
Identification Supervisor (IDS): (E-5)	between 3-8	$14

Note: Costs calculated by averaging monthly salary plus sea pay for the assumed ranks at low/high estimates of years in service.

Actions per Hour: A triangular distribution with min/max/most-likely values based on calculations from the following numbers.

	Costal	Open Water	High Density
Number of Contacts per Hour	24-42	12-30	28-66
Time in Location	15%	25%	60%

Note: Data provided by SMEs

[16] In the case of a TAO, assume 80% of the time the position is filled by an 0-5; in the case of an IDS, assume 80% or the time the position is filled by an E-5.

Appendix B. KVA Results by Watch Station

	Tactical Action Officer				Anti-Air Warfare Coordinator				Surface Warfare Coordinator			
	"AS IS"	"TO BE"	"RAD 1"	"RAD 2"	"AS IS"	"TO BE"	"RAD 1"	"RAD 2"	"AS IS"	"TO BE"	"RAD 1"	"RAD 2"
CORRELATE												
Obtain Link Information	3625%	3450%	3206%	2717%	5091%	4907%	4525%	3979%	2441%	2304%	2230%	2044%
Identify "Same Contact,Multiple Track"	-91%	-91%	2104%	1778%	-87%	-87%	2983%	2619%	-94%	-94%	1453%	1329%
Verify Other Track Sources	-94%	-94%	-95%	-96%	-92%	-92%	-93%	-94%	-96%	-96%	-96%	-97%
Correlate Sub-Total	***1358%***	***1290%***	***1791%***	***1512%***	***1932%***	***1860%***	***2546%***	***2233%***	***497%***	***465%***	***476%***	***431%***
TRACK												
Monitor Suspect Tracks	-98%	-99%	-99%	-99%	-98%	-98%	-98%	-98%	-99%	-99%	-99%	-99%
Update Tracks	-97%	-97%	294%	235%	-96%	-96%	451%	386%	-98%	-98%	177%	155%
Update GCCS-M	-95%	173%	154%	117%	-	-	-	-	-97%	85%	79%	65%
Track Sub-Total	***-98%***	***-97%***	***-85%***	***-87%***	***-97%***	***-97%***	***-50%***	***-56%***	***-97%***	***-55%***	***47%***	***36%***
IDENTIFY												
Verify IFF signal	645%	610%	561%	463%	938%	901%	825%	716%	408%	381%	366%	329%
Verify EW emissions	-89%	-89%	-90%	540%	-89%	-91%	-92%	827%	-92%	-93%	-93%	387%
Verify Point of Origin	-98%	3450%	3206%	2717%	-97%	4907%	4525%	3979%	-99%	2304%	2230%	2044%
Match Against ATO	-98%	3450%	3206%	2717%	-97%	4907%	4525%	3979%	-	-	-	-
Match Against CommAir Profile	831%	788%	727%	604%	1198%	1152%	1056%	920%	-	-	-	-
Match Against Intel Information	-97%	-97%	-97%	3813%	-96%	-96%	-96%	5565%	-98%	-98%	-98%	2878%
Examine Kinematic Data	-96%	-96%	-97%	-97%	-95%	-95%	-95%	-96%	-97%	-98%	-98%	-98%
Obtain Visual ID	-100%	-100%	-100%	-100%	-100%	-100%	-100%	-100%	-100%	-100%	-100%	-100%
Conduct Verbal Query	-99%	-99%	-99%	-99%	-99%	-99%	-99%	-99%	-99%	-99%	-99%	-99%
Identify Sub-Total	***55%***	***152%***	***134%***	***596%***	***84%***	***197%***	***174%***	***689%***	***-95%***	***-93%***	***-93%***	***-26%***
RELAY												
Send Over Links	-91%	-91%	-92%	-93%	-87%	-87%	-88%	-90%	-94%	-94%	-94%	-95%
Discuss Picture with Battle Force Units	-99%	-99%	-99%	-99%	-98%	-98%	-98%	-99%	-99%	-99%	-99%	-99%
Relay Sub-Total	***-98%***	***-100%***	***-100%***	***-100%***	***-98%***	***-98%***	***-98%***	***-98%***	***-99%***	***-100%***	***-100%***	***-100%***
TOTAL	***306%***	***347%***	***389%***	***558%***	***354%***	***400%***	***451%***	***640%***	***9%***	***13%***	***17%***	***64%***

Figure B-1. AEGIS ROI Estimates

	Combat Systems Coordinator				Tactical Information Coordinator				Identification Supervisor			
	"AS IS"	"TO BE"	"RAD 1"	"RAD 2"	"AS IS"	"TO BE"	"RAD 1"	"RAD 2"	"AS IS"	"TO BE"	"RAD 1"	"RAD 2"
CORRELATE												
Obtain Link Information	1040%	1034%	937%	743%	5012%	4889%	4510%	4146%	5921%	5772%	5312%	4870%
Identify "Same Contact, Multiple Track"	-97%	-97%	591%	462%	-87%	-88%	2973%	2731%	-85%	-85%	3508%	3213%
Verify Other Track Sources	-98%	-98%	-98%	-99%	-92%	-92%	-93%	-93%	-91%	-91%	-92%	-92%
Correlate Sub-Total	***346%***	***344%***	***493%***	***383%***	***1901%***	***1853%***	***2537%***	***2329%***	***2257%***	***2199%***	***2996%***	***2743%***
TRACK												
Monitor Suspect Tracks	-100%	-100%	-100%	-100%	-98%	-98%	-98%	-98%	-97%	-98%	-98%	-98%
Update Tracks	-99%	-99%	65%	34%	-96%	-96%	449%	405%	-96%	-96%	544%	492%
Update GCCS-M	-	-	-	-	-	-	-	-	-	-	-	-
Track Sub-Total	***-99%***	***-99%***	***-94%***	***-96%***	***-97%***	***-97%***	***-5%***	***-13%***	***-97%***	***-97%***	***11%***	***2%***
IDENTIFY												
Verify IFF signal	128%	127%	107%	69%	922%	898%	822%	749%	1104%	1074%	982%	894%
Verify EW emissions	-96%	-96%	-97%	113%	-85%	-85%	-86%	865%	-82%	-82%	-84%	1030%
Verify Point of Origin	-99%	1411%	1282%	1025%	-97%	4889%	4510%	4146%	-97%	5772%	5312%	4870%
Match Against ATO	-99%	1411%	1282%	1025%	-97%	4889%	4510%	4146%	-97%	5772%	5312%	4870%
Match Against CommAir Profile	280%	278%	246%	181%	1178%	1147%	1053%	962%	1405%	1368%	1253%	1142%
Match Against Intel Information	-99%	-99%	-99%	1462%	-96%	-96%	-96%	5797%	-95%	-95%	-95%	6803%
Examine Kinematic Data	-98%	-98%	-99%	-99%	-95%	-95%	-95%	-96%	-94%	-94%	-95%	-95%
Obtain Visual ID	-	-	-	-	-100%	-100%	-100%	-100%	-99%	-100%	-100%	-100%
Conduct Verbal Query	-	-	-	-	-99%	-99%	-99%	-99%	-98%	-99%	-99%	-99%
Identify Sub-Total	***-54%***	***-50%***	***-54%***	***148%***	***21%***	***69%***	***56%***	***242%***	***99%***	***182%***	***160%***	***503%***
RELAY												
Send Over Links	-96%	-96%	-97%	-97%	-87%	-88%	-88%	-89%	-85%	-85%	-86%	-88%
Discuss Picture with Battle Force Units	-	-	-	-	-98%	-98%	-98%	-99%	-98%	-98%	-98%	-98%
Relay Sub-Total	***-96%***	***-100%***	***-100%***	***-100%***	***-98%***	***-100%***	***-100%***	***-100%***	***-95%***	***-95%***	***-95%***	***-96%***
TOTAL	***54%***	***56%***	***73%***	***162%***	***228%***	***258%***	***297%***	***423%***	***298%***	***335%***	***382%***	***535%***

Figure B-2. AEGIS ROI Estimates (cont.)

	Tactical Action Officer				Anti-Air Warfare Coordinator				Surface Warfare Coordinator			
	"AS IS"	**"TO BE"**	**"RAD 1"**	**" RAD 2"**	**"AS IS"**	**"TO BE"**	**"RAD 1"**	**" RAD 2"**	**"AS IS"**	**"TO BE"**	**"RAD 1"**	**" RAD 2"**
CORRELATE												
Obtain Link Information	2129%	2025%	1871%	1578%	3006%	2896%	2655%	2329%	1420%	1339%	1292%	1181%
Identify "Same Contact, Multiple Track"	-94%	-95%	1477%	1243%	-92%	-93%	2104%	1843%	-96%	-96%	1013%	925%
Verify Other Track Sources	-97%	-97%	-97%	-97%	-95%	-95%	-96%	-96%	-98%	-98%	-98%	-98%
Correlate Sub-Total	***773%***	***732%***	***1045%***	***876%***	***1116%***	***1073%***	***1502%***	***1312%***	***257%***	***238%***	***245%***	***217%***
TRACK												
Monitor Suspect Tracks	-99%	-99%	-99%	-99%	-99%	-99%	-99%	-99%	-99%	-99%	-99%	-99%
Update Tracks	-98%	-98%	182%	140%	-98%	-98%	294%	247%	-99%	-99%	99%	83%
Update GCCS-M	-97%	63%	52%	29%	-	-	-	-	-98%	11%	7%	-1%
Track Sub-Total	***-99%***	***-98%***	***-91%***	***-92%***	***-98%***	***-98%***	***-70%***	***-73%***	***-98%***	***-73%***	***-8%***	***-15%***
IDENTIFY												
Verify IFF signal	346%	325%	294%	236%	521%	499%	451%	386%	204%	188%	178%	156%
Verify EW emissions	-93%	-94%	-94%	281%	-91%	-91%	-92%	452%	-95%	-96%	-96%	191%
Verify Point of Origin	-99%	2025%	1871%	1578%	-98%	2896%	2655%	2329%	-99%	1339%	1292%	1181%
Match Against ATO	-99%	2025%	1871%	1578%	-98%	2896%	2655%	2329%	-	-	-	-
Match Against CommAir Profile	457%	431%	393%	320%	677%	649%	589%	507%	-	-	-	-
Match Against Intel Information	-98%	-98%	-98%	2231%	-97%	-98%	-98%	3273%	-99%	-99%	-99%	1679%
Examine Kinematic Data	-98%	-98%	-98%	-98%	-97%	-97%	-97%	-98%	-98%	-99%	-99%	-99%
Obtain Visual ID	-100%	-100%	-100%	-100%	-100%	-100%	-100%	-100%	-100%	-100%	-100%	-100%
Conduct Verbal Query	-99%	-99%	-100%	-100%	-99%	-99%	-99%	-99%	-100%	-100%	-100%	-100%
Identify Sub-Total	***-7%***	***51%***	***40%***	***314%***	***10%***	***78%***	***64%***	***370%***	***-97%***	***-96%***	***-96%***	***-56%***
RELAY												
Send Over Links	-94%	-95%	-95%	-96%	-92%	-93%	-93%	-94%	-96%	-96%	-97%	-97%
Discuss Picture with Battle Force Units	-99%	-99%	-99%	-99%	-99%	-99%	-99%	-99%	-99%	-100%	-100%	-100%
Relay Sub-Total	***-99%***	***-100%***	***-100%***	***-100%***	***-99%***	***-99%***	***-99%***	***-99%***	***-99%***	***-100%***	***-100%***	***-100%***
TOTAL	***143%***	***168%***	***193%***	***294%***	***172%***	***199%***	***230%***	***343%***	***-35%***	***-33%***	***-30%***	***-2%***

Figure B-3. SSDS ROI Estimates

	Combat Systems Coordinator				Tactical Information Coordinator				Identification Supervisor			
	"AS IS"	**"TO BE"**	**"RAD 1"**	**" RAD 2"**	**"AS IS"**	**"TO BE"**	**"RAD 1"**	**" RAD 2"**	**"AS IS"**	**"TO BE"**	**"RAD 1"**	**" RAD 2"**
CORRELATE												
Obtain Link Information	2628%	2613%	2370%	1907%	9076%	8856%	8141%	7487%	10708%	10441%	9572%	8779%
Identify "Same Contact, Multiple Track"	-93%	-93%	1876%	1505%	-77%	-78%	6492%	5970%	-73%	-74%	7638%	7003%
Verify Other Track Sources	-96%	-96%	-96%	-97%	-86%	-86%	-87%	-88%	-83%	-84%	-85%	-86%
Correlate Sub-Total	***968%***	***962%***	***1336%***	***1066%***	***3492%***	***3406%***	***4690%***	***4310%%***	***4131%***	***4027%***	***5522%***	***5061%***
TRACK												
Monitor Suspect Tracks	-99%	-99%	-99%	-99%	-96%	-96%	-97%	-97%	-95%	-96%	-96%	-96%
Update Tracks	-98%	-98%	253%	187%	-93%	-94%	1077%	984%	-92%	-92%	1282%	1168%
Update GCCS-M	-	-	-	-	-	-	-	-	-	-	-	-
Track Sub-Total	***-99%***	***-99%***	***-90%***	***-92%***	***-95%***	***-95%***	***75%***	***61%***	***-94%***	***-94%***	***105%***	***88%***
IDENTIFY												
Verify IFF signal	446%	443%	394%	301%	1735%	1691%	1548%	1417%	2062%	2008%	1834%	1676%
Verify EW emissions	-92%	-92%	-93%	356%	-72%	-73%	-75%	1624%	-68%	-68%	-71%	1918%
Verify Point of Origin	-99%	2613%	2370%	1907%	-95%	8856%	8141%	7487%	-95%	10441%	9572%	8779%
Match Against ATO	-99%	2613%	2370%	1907%	-95%	8856%	8141%	7487%	-95%	10441%	9572%	8779%
Match Against CommAir Profile	582%	578%	517%	402%	2194%	2139%	1960%	1797%	2602%	2535%	2318%	2120%
Match Against Intel Information	-98%	-98%	-98%	2687%	-92%	-93%	-93%	10437%	-91%	-91%	-92%	12231%
Examine Kinematic Data	-97%	-97%	-98%	-98%	-91%	-91%	-92%	-92%	-89%	-89%	-90%	-91%
Obtain Visual ID	-	-	-	-	-99%	-99%	-99%	-99%	-99%	-99%	-99%	-99%
Conduct Verbal Query	-	-	-	-	-98%	-98%	-98%	-98%	-97%	-97%	-98%	-98%
Identify Sub-Total	***-17%***	***-9%***	***-17%***	***346%***	***118%***	***203%***	***179%***	***512%***	***257%***	***406%***	***364%***	***977%***
RELAY												
Send Over Links	-93%	-93%	-94%	-95%	-77%	-78%	-79%	-81%	-73%	-74%	-76%	-78%
Discuss Picture with Battle Force Units	-	-	-	-	-97%	-97%	-97%	-97%	-96%	-96%	-97%	-97%
Relay Sub-Total	***-93%***	***-100%***	***-100%***	***-100%***	***-96%***	***-100%***	***-100%***	***-100%***	***-91%***	***-91%***	***-92%***	***-92%***
TOTAL	***256%***	***260%***	***300%***	***459%***	***489%***	***544%***	***613%***	***839%***	***615%***	***682%***	***766%***	***1040%***

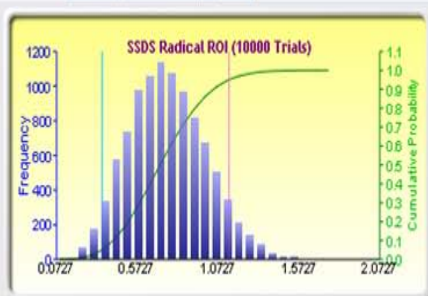
Figure B-4. SSDS ROI Estimates (cont.)

Appendix C. Real Options Analysis

Billet	Contact ID Subprocess	Number of Personnel	ApH Min	Actions per Hour	APH ADD	APH REP	ApH Max	-5%	AWT (Hours)	5%	-5%	ALT (Hours)	5%	NLT
Tactical Action Officer (TAO)	**CORRELATE**													
	Obtain Link Information	1	64	256	256	256	332.8	0.0016	0.00164	0.0017	7.6	8.0	8.4	2.0
	Identify "Same Contact, Multiple Track"	1	10	40	70	160	52	0.0016	0.00166	0.0017	7.6	8.0	8.4	1.0
	Verify Other Track Sources	1	5	20	20	20	26	0.0156	0.01647	0.0173	9.5	10.0	10.5	3.0
	TRACK													
	Monitor Suspect Tracks	1	6.25	25	25	25	32.5	0.0230	0.02426	0.0255	3.8	4.0	4.2	3.0
	Update Tracks	1	2.5	10	16.5	28.57143	13	0.0016	0.00170	0.0018	1.9	2.0	2.1	2.0
	Update GCCS-M	1	0.5	2	2.7	3.076923	2.6	0.0015	0.00163	0.0017	1.9	2.0	2.1	1.0
	IDENTIFY													
	Verify IFF signal	1	32	128	128	128	166.4	0.0016	0.00173	0.0018	7.6	8.0	8.4	8.0
	Verify EW emissions	1	6.25	25	25	25	32.5	0.0083	0.00869	0.0091	5.7	6.0	6.3	5.0
	Verify Point of Origin	1	3	12	23.4	240	15.6	0.0015	0.00159	0.0017	1.9	2.0	2.1	3.0
	Match Against ATO	1	5	20	39	400	26	0.0015	0.00162	0.0017	1.9	2.0	2.1	6.0
	Match Against CommAir Profile	1	32	128	128	128	166.4	0.0016	0.00167	0.0018	1.9	2.0	2.1	4.0
	Match Against Intel Information	1	6.25	25	25	25	32.5	0.0238	0.02509	0.026	9.5	10.0	10.5	9.0
	Examine Kinematic Data	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Obtain Visual ID	1												
	Conduct Verbal Query	1												
	RELAY													
	Send Over Links	1												
	Discuss Picture with Battle Force Units	1												
	Totals													
Anti Air Warfare Coordinator	**CORRELATE**													
	Obtain Link Information	1												
	Identify "Same Contact, Multiple Track"	1												
	Verify Other Track Sources	1												
	TRACK													
	Monitor Suspect Tracks	1												
	Update Tracks	1												
	Update GCCS-M	0												
	IDENTIFY													
	Verify IFF signal	1	32	128	128	128	166.4	0.0016	0.00167	0.0018	7.6	8.0	8.4	8.0
	Verify EW emissions	1	6.25	25	25	25	32.5	0.0079	0.00833	0.0088	5.7	6.0	6.3	5.0
	Verify Point of Origin	1	3	12	23.4	240	15.6	0.0016	0.00167	0.0018	1.9	2.0	2.1	3.0
	Match Against ATO	1	5	20	39	400	26	0.0016	0.00167	0.0018	1.9	2.0	2.1	6.0
	Match Against CommAir Profile	1	32	128	128	128	166.4	0.0016	0.00167	0.0018	1.9	2.0	2.1	4.0
	Match Against Intel Information	1	6.25	25	25	25	32.5	0.0238	0.02500	0.0263	9.5	10.0	10.5	9.0

SSDS Radical ROI - Risk Simulator Forecast

Histogram | Statistic | Preferences | Options



Type: Two-Tail | 0.3549 | 1.1396 | Certainty (%) 90.00

SSDS Radical ROI - Risk Simulator Forecast

Histogram | Statistic | Preferences | Options

Statistics	Result
Number of Trials	10000
Mean	0.7263
Median	0.7130
Standard Deviation	0.2388
Variance	0.0570
Average Deviation	0.1924
Maximum	1.7528
Minimum	0.0279
Range	1.7249
Skewness	0.3014
Kurtosis	-0.0963
25% Percentile	0.5520
75% Percentile	0.8862
Percentage Error Precision at 95% Confidence	0.6446%

Table C-2. KVA Analysis with Monte Carlo Risk-based Simulations

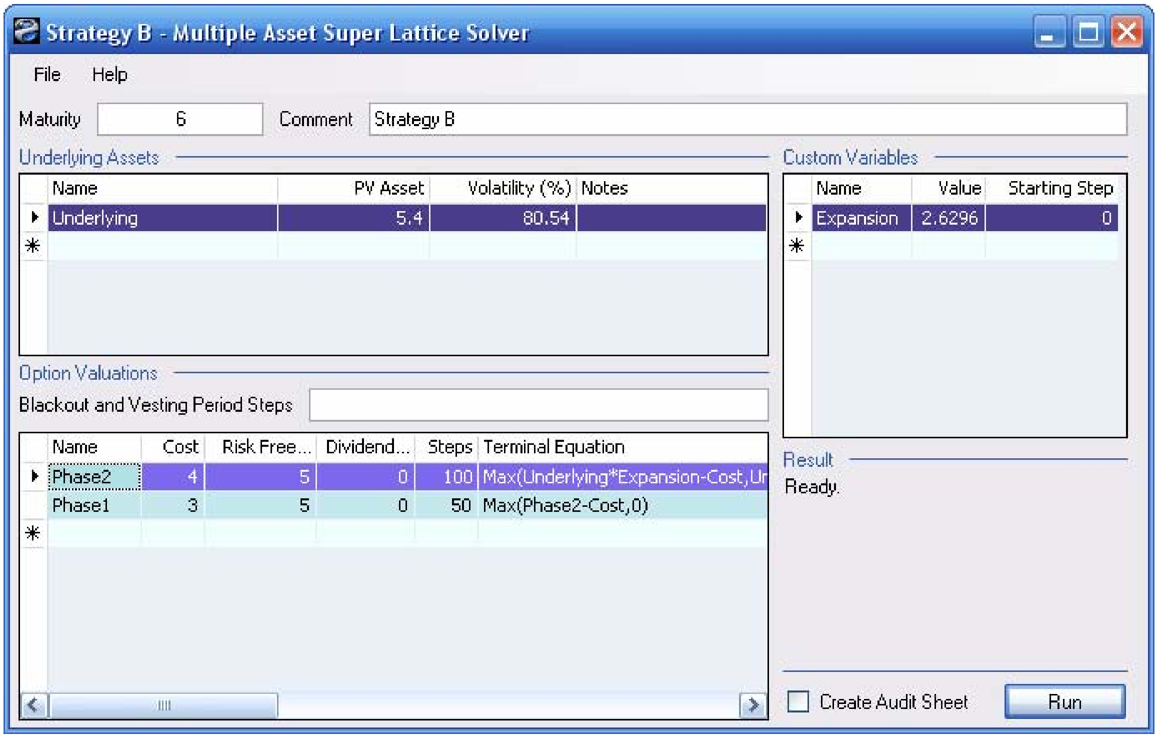


Table C-3. Strategy B: Real Options Analysis Results

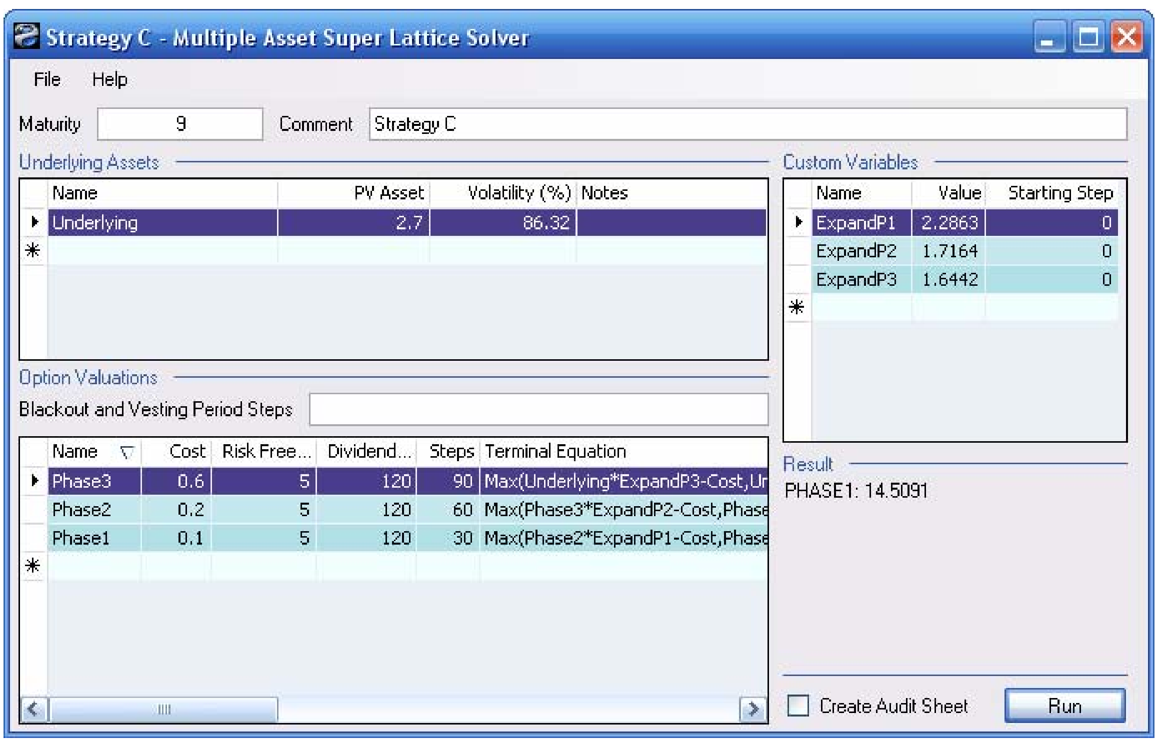


Table C-4. Strategy C: Real Options Analysis Results

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Measuring the Value Added of Management: A Knowledge Value Added Approach

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Introduction

That management adds value to organizations is one of the unquestioned truisms of business, government, military, and any other multi-member organization. The question left largely unanswered is, "How much value does management add to an organization?" The

central research focus of this study is to establish a method for objectively measuring the value management adds to an organization.

Determining the value added by management becomes particularly important as Navy acquisition managers deal with increasingly complex, open business models that engage many more participants in the development and implementation of products and services to support warfighters. There is a recognition that emerging, increasingly complex acquisition environments require more direction, collaboration, and control to achieve the reductions in costs as well as the increases in warfighting effectiveness that initiatives, such as the Open Architecture (OA) system acquisition and development framework, promise. The increasing burden on management in such environments largely derives from the amount of complexity managers must deal with by attempting to mitigate risks, improve predictions, and exercise the control and oversight necessary to be successful.

Determining the value added by management is important because:

- Managers need to know how well they are performing in more complex and demanding environments such as OA and open business models.
- Those who evaluate management performance need a common metric to gauge the degree to which managers are succeeding or failing.
- Poor performance by management threatens delivery time, acquisition costs, and capability of acquired products and services.
- A consistent and objective way to evaluate management provides historical performance data that leads to more precise risk estimates (instead of uncertainty-based guesses).
- Including management performance in the overall assessment of organizational performance provides a more complete picture of how well an organization is performing.

Objectivity Needed

Solving this problem requires a new and more objective approach to measuring the value added by management than previous efforts. Subjective approaches and approaches based on corporate-level residuals—which presumably are a result of management activity—will not provide the kinds of precision necessary to allocate value (e.g., revenue, outputs) to individual managers in proportion to the amount they contribute to the organization’s value stream.

Management literature is replete with the characteristics, motivations, and general mantras regarding what it takes to develop and sustain great managers. There are even more articles, books, motivational tapes and videos on what it takes to become a great leader. Undoubtedly, these suggestions can lead to great management. However, without a way to partition the actual, countable contributions that management makes to the corporate bottom line or general organizational success, there will be no way to tell which suggestions really work and which add little or no marginal value.

Research Focus

This research will focus on making the case for a method to objectively measure the value added by management activities. We will review the general issues involved in developing a theoretically sound, rigorous, and pragmatic approach to estimating the value added by management. The paper will conclude with an example of how this approach would work in an open acquisitions environment.

Management "Dark Matter"

Dark matter, in the physics sense, is largely unobservable—albeit critical to understanding the physics of the universe. The dark matter of management has also been largely unobservable in the outputs of the core processes of an organization, although it is also critical to understanding the functioning of an organization.[17] These mysterious elements are the managing activities that guide the organization toward its future and are assumed to be associated with the market outcomes (e.g., increases or decreases in revenue, military capability) managers attempt to influence.

Management activities contribute directly to the outputs of the processes that are being managed, but they also involve the use of managers' creative insights when they attempt to predict the future, create potential pathways to accomplish the predictions, and control for future risks and uncertainties. Those activities that are uniquely associated with management involve the creative use of decision heuristics based on managers implicit knowledge accumulated over years of experience, training and education. We label this creative aspect as management "dark matter." This management "dark matter" has largely been assumed to be critical to the duties of a manager but has not been objectively measured as researchers attempted to account for the value added by management.

These heuristics from management's dark matter are not algorithmically definable and previously have been subsumed within the standard knowledge value added (KVA) methodology in gross estimates of the overall output of an organization at a given point in time. Basic KVA theory is designed specifically for all processes, activities that are algorithmically definable a priori, i.e., for processes with predetermined outputs (Housel & Kanevsky, 1995). KVA posits an analytic tautology that assumes that historical outputs of an organization at a given point in time can be described in common units and, therefore, can be counted in absolute terms. Further, the total revenue of a commercial organization is equivalent to the total number of common units of output at a given point in time. The theory must now be expanded to account for those managing activities that involve creative attempts to resolve risk, uncertainty and take advantage of upside potential.

To maintain the historical and analytic context of KVA, we will provide a way to count the management dark matter activities within estimates of the overall output of the organization at a given point in time. This is reasonable given the fact that previous dark matter activities can be found in current process outputs; they usually take the form of changes to those process descriptions that lead to new or changed outputs.

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[17] Notionally, the grey (dark) matter of the brain also is where original thinking occurs.

For instance, in an open-business-model environment, if an acquisition manager suggests that a vendor change some aspect of his/her core processes to ensure that a project stay on schedule, and the vendor responds by changing his/her process to mitigate the perceived risk, then the acquisition manager's dark matter will eventually be manifested in the changed process. This example assumes that the acquisition manager and vendor are part of a virtual organization working collaboratively toward a final outcome, e.g., an integrated weapons system.

In the ARCI (Acoustic Rapid COTS Insertion) program, an open architecture (OA), open-acquisition business model was used to rapidly transition new technologies from the Advanced Submarine Technology Office (ASTO) housed within the Program Executive Office-Integrated Weapons Systems (PEO-IWS) and the ARCI program (housed within a different program office, i.e., PEO Subs). This created an increase in the complexity of the acquisition cycle. However, it also allowed the ARCI program to leverage the resources and outputs of the ASTO program when it created an inter-program partnership. The OA, open-business model provided the environment that created this opportunity as well as contributed to the increased complexity. In this environment, the ARCI acquisition management had to use more of its dark matter to ensure closer collaboration among the various parties as well as to predict and mitigate possible uncertainties and risks while leveraging the multiple resources of the "virtual" organization.

Accounting for the value added by acquisition managers, in this case, is more than just accounting for their routine process contributions; it also requires accounting for their use of dark matter capabilities to influence the future behavior of the virtual organization. If the acquisition manager is really "doing his/her job" in this open business environment, s/he will constantly be using this dark matter to attempt to control risks and uncertainties by predicting the future actions necessary to mitigate same.

This manager can no longer be content to simply ensure that the vendor meets the stipulated contract obligations. In the new open environment, the acquisitions manager must now coordinate with numerous potential contractors throughout the life cycle of the system acquisition. These must become a part of a virtual management team that collaborates regularly to ensure that the developing (or developed) system meets the needs of the warfighter. This new, more complex environment introduces greater opportunities for the manager to use his/her dark matter to creatively anticipate and solve problems while also seeking better ways to satisfy the constantly changing warfighter requirements.

Difficult-to-track Dark Matter Outputs

This dark matter aspect of his/her job has been more difficult to track in objective terms and largely has been relegated to anecdotal descriptions of the occasional successes and failures in the use of dark matter capabilities. These managers' job descriptions include directions to use their dark matter capabilities to control for risks, such as potentially slipping development and implementation schedules. However, it is often more easy for them to simply focus on the daily routines of "putting out fires" than to stretch their dark matter capacities to innovate when necessary to mitigate future risks and capitalize on future opportunities—in other words, to increase warfighting capabilities.

We can use standard KVA methodology to track the outputs of this dark matter activity over time since it has been assumed to be a part of the organization's overall output

at a given point in time. As such, it is assumed to be a required part of the manager's standard outputs and, thus, can be counted within the standard KVA methodology. However, we also assume that this dark matter output will have some influence on the marketplace. Therefore this output should correlate with changes in the market, such as increased sales.

Computing Metaphor

Another way to describe management dark matter conceptually is by using a computing metaphor as has been used previously to describe the KVA methodology (Kanevsky & Housel, 1998). Using a computing analogy, managers use their dark matter capabilities to *write the program* for the processes they manage. "*Writing*" the program includes:

- decisions they must make during the course of a given time period, including:
    - Deciding which "program" to use
    - Deciding how to allocate resources to produce given outputs
    - Sustaining activities that maintain his/her network
    - Forecasting the amount of outputs desired from the processes he/she manages
    - Creating, sending, and receiving messages
    - Selecting and using technology to support management activities

Writing the program is how managers create value in the processes they manage. The time it takes to write the program to produce a given output is the cost of managing. The actual, non-redundant length of the program is proportionate to the value of the program (Housel & Kanevsky, 1995). More complex dark matter decisions require longer programs, and simpler decisions require shorter programs. Writing a relatively long program that includes significant amounts of redundancy and does not execute or executes poorly is how managers increase costs—relative to managers who write shorter, i.e., more elegant, programs that produce the same outputs. This can be likened to the "art of good management."

Technology can support managers in producing their dark matter outputs. For example, in an open acquisitions environment, collaborative technology can support a manager in recording, distributing, and receiving messages. However, while "managing technology" may execute some routine management activities, there is no program, at this point, that can write its own unique program. This makes the position of the managers

unique because, at this point in time,[18] it is their ability to create elegant programs that largely determines their success in managing.

The ability of a manager to write elegant programs that produce the desired amount and kinds of process outputs, largely determines his/her value added to the enterprise. If they write programs that predict poorly, managers will fail to allocate resources properly and, thus, fail to produce the desired outputs. This will be evidenced by overall lower returns on investment (ROIs) on given processes due to relatively poor utilization of process assets such as technology and employees.

Elegant, parsimonious, and precise management “programmers” will produce the best outcomes over time. This may be due to a variety of reasons, including: employees that are happier because they are more productive, the ability of management to respond quickly to changes in markets-environments, and higher utilization of technology assets based on more optimized process designs. There may be a variety of outcomes due to more elegant programs; however, regardless of outcome, elegant programs will result in higher ROIs in managing.

Dark Matter Correlates with Market Performance

We recognize that these dark matter activities are meant to influence the future behavior of the core processes of organizations to achieve the management goals established for the organization. As such, they should be correlated with the market performance of the organization in terms of the impact on outcomes obtained by organizations (e.g., increased capabilities, winning the battle, more revenue, or other forms of value).

The seeming conundrum is that while these dark matter activities are designed to influence future behavior and outcomes, historically, they can be accounted for at a given point in time. That they are part of the output of an organization at a given point in time is clear; however, they cannot be tied directly to the current outputs of the organization that produce the value or capabilities that markets are willing to purchase.

For example, in our new open business environment in which all parties are part of a collaborative virtual organization, an acquisition manager would feel free to suggest a potential risk mitigation strategy to a contractor because he/she assumes that the development schedule will slip due to the loss of a key programmer. With the required increase in collaboration among the contractor and the other parties involved in the development and deployment of a new integrated weapons system (IWS), precipitated by the use of an OA and open-business-model approach, managers of every group must engage in greater cooperation across organizational boundaries. To be successful, they all must use their collective dark matter capabilities to recognize and address potential risks and opportunities.

In this new cooperative environment, whether the acquisition manager’s or the contractor’s dark matter activity is directly responsible for changes to IWS development

[18] Ray Kurzweil (In the *Age of Spiritual Machines*) argues that computers will have the intelligence to write their own unique programs within the next 50 years.

processes cannot be known unambiguously—e.g., "Was it the acquisition manager or the contractor manager that was responsible for the changed process that avoided the possible schedule slippage?" The only thing that is unambiguous is that both have produced the outputs from their collective dark matter capabilities, and these should be treated as coming from a single management entity. They should, therefore, be less inclined to point fingers when things go wrong due to poor use of management dark matter and more inclined to ensure that the IWS is delivered on time, with the capabilities required by the warfighter.

In addition, the cooperative use of dark matter to achieve common goals will ensure that managers make the adjustments necessary to seize opportunities to create greater capabilities in the IWS when deemed necessary by the warfighter. Tracking their collective use of dark matter makes it possible to assess the contributions of the new collaborative cross-organizational management team. There is nothing quite like being measured on overall performance to drive home the need for cooperation to achieve common goals.

Outputs of Dark Matter

If we assume that these dark matter outputs are a necessary part of the output of an organization—and this would appear to be the case in terms of our expectations for as least part of what managers should be doing: i.e., predicting the future and controlling for risk—then it follows that these dark matter activities of management are, a priori, designed to be part of the output of the organization. Indeed, a review of management job descriptions would include imperatives to "lead, motivate, plan for the future, control risks," all of which we are labeling dark matter activities.

For example, if a manager uses his/her creative insight to suggest that the product should be painted green as well as red, the painting process eventually must be changed to reflect the prediction that the new color for the product will sell better to a given segment of the market.

Or, for example, when an acquisition manager senses that the schedule is about to slip because a subcontractor has gone bankrupt, he/she must predict the effect of this risk and develop strategies to mitigate the problem, such as maintaining an option to purchase the service from another developer. Another example might be when the "manager" (officer) of a warfighting process that tracks ships in a congested area, such as the Persian Gulf, recognizes that something is amiss even though the track information appears to be correct. His intuition, based on the dark matter acquired over years of experience, comes into play in seeking further clarification of the track information because something (his intuition, or dark matter) tells him all is not well, and this ship may not be "friendly".

Operationalizing: The Measurement of Dark Matter

We assume that managers constantly acquire knowledge both formally and informally, learn from that knowledge, and incorporate that knowledge in their decision-making in predicting the future and in planning to control for risk and uncertainty from a constantly changing environment. This form of management "dark matter" output is manifested largely in the messages that managers generate, distribute and interpret to predict and control core processes to accomplish the goals of the organization. Most of a manager's time is spent in creating, sending, receiving and interpreting messages. These messages are basic descriptions of actions the manager is influencing his organization to

take. Some of these actions are unambiguously tied to actual production of the process they are managing and, thus, are captured in the standard KVA methodology within the description of process outputs.

The central idea is that we can “see” the manifestation of that acquired knowledge and the subsequent managing activities via the networks that managers and information technology (e.g., collaborative technology) use to create, send, and receive messages. These messages are sent to and received from the employees and the technology.[19] The actual contents of the messages take many forms and fill many purposes—all of which can be described in the common descriptive language provided by the KVA approach in terms of their relative complexity.

The challenge is to develop an operationalization of management dark matter outputs that permits an objective bifurcation of relevant and irrelevant activities without resorting to overly subjective interpretations and the potential biases such subjective judgments introduce. At the very least, the goal should be to establish an unambiguous principle for categorizing relevant and irrelevant activities that is defensible without resorting to subjective judgment. This bifurcation will be worked out as we attempt to operationalize this approach over time with actual case studies and empirical research.[20]

Those messages that are unambiguously tied to current process outputs represent routine management outputs that are measurable in the standard KVA methodology. Those management messages that are not found directly in current outputs of the process are evidence of management dark matter activity. Regardless of their semantic content, because we can observe all the messages and estimate their complexity, they represent a convenient way to observe and measure management dark matter outputs.

Management Dark Matter Outputs and Job Descriptions

Top executives often state goals in broad sweeping terms such as “We will move from product leadership to cost leadership within the next three years; We will move from a proprietary, closed business model to an open business model in acquisitions.” Such

[19] Future research may establish a more refined measure of dark matter activity and outputs by examining the networks managers create, modify and use to receive and distribute their messages. These networks vary in terms of their complexity; the messages sent and received also vary in complexity. These two forms of complexity can be described in terms of the knowledge required to reproduce them, and the knowledge can be described in common units using the KVA approach. With this information, we can measure the amount of knowledge transferred through each link in the network—including the knowledge used to maintain and modify the network.

[20] The basic problem is to determine what aspects of this management dark matter are relevant to organizational value and which are not directly relevant. It is possible to semantically interpret management activities as relevant or irrelevant to the organization. For example, when a manager arranges a dinner date with his/her spouse, it is very likely this activity was irrelevant to achieving organizational goals. However, when we examine less obvious examples, such as a manager musing about whether to invest in a new technology that may or may not ever be purchased, it is less obvious how this activity led to some organizational outcome.

broadly stated goals must be translated into action at the process level through changes in the process descriptions (e.g., make more widgets or make different kinds of widgets).

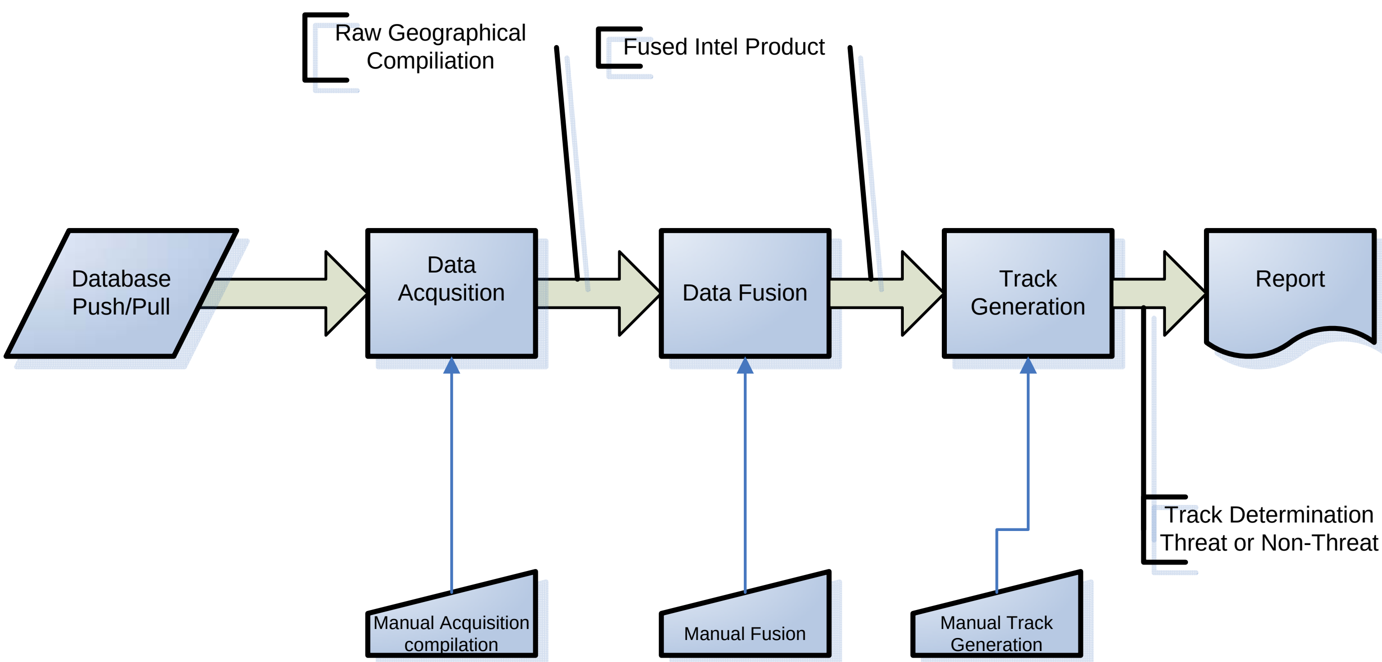
Management job descriptions should reflect the dark matter capabilities necessary to translate such broad, sweeping goals into operational realities. One way to measure dark matter output would be to examine the job descriptions of managers and ask them to estimate how many messages and/or activities they generate to fulfill each aspect of the job, as well as how often they do this within a given time period. To check the accuracy of manager's self reports, we can check actual message logs, e-mails, other text-based historical records to ensure there is a high enough level of reliability among the estimates to proceed.

It would also be possible to ask them to generate a more precise job description if the original is not sufficiently reflective of what they really do. The next step would be to separate the duties that involve routine daily operations and those that are more reflective of management dark matter activities.

Case Example: Ship Tracking Process

There are approximately 250K ships at sea world-wide at any given point in time. The US military needs to know which are friendly and which are potential foes. The responsibility for tracking these ships currently rests with the Coast Guard. The tracking process must be managed by experienced Watch Commanders who can intuitively sense when a given track is incorrect (Figure 1). This ability cannot be automated at this point in time and is, therefore, indicative of dark matter. Watch Commanders must be able to anticipate when risks of false identification of tracks may be present.

Figure 1. Ship Tracking Process



Ship Tracking Management's Dark Matter Activities

The track manager and his watch commander must supervise the process to ensure that timely and accurate information is provided to various DoD entities to help them achieve situational awareness (SA). The primary job of management is to ensure its subordinates are correctly tracking the ship activity. One method by which members of management check tracking is the quality control step, in which managers must sign off on track reports as accurate.

In this environment, there are times when the managers intuitively recognize that the track information may not be correct—even though they may not be completely aware of why they have made such judgments. Their intuitions lead them to ask their subordinates to re-run the track information gathering to ensure its accuracy. Their use of dark matter results in communications/messages, to subordinates to rerun the tracking process on given suspect targets. As such, the communications are observable applications of their dark matter and can be described via the standard KVA methodology.

The times when intuitions are correct or incorrect also can be counted. If we take a conservative attribution strategy, we will only count the correct ones, those ships that turned out to be incorrectly tracked and categorized, as part of management's dark matter output. However, it can also be argued that to achieve a given yield rate for suspected tracks, management must have some level of false positives; therefore, all should be counted as management dark matter outputs. In either case, this simple case example enabled us to identify and count those dark matter outputs of management which in turn allowed us to allocate value to those activities.

In this case example, we have also demonstrated that when a simple dark matter capability can be explicitly described (i.e., we may uncover the heuristic decision-making process that managers used to identify the potential incorrect tracks), it becomes possible to capture this dark matter capability in intelligent computer programs such as expert systems. This is the basis for many expert systems that embed management dark matter decision capabilities within their code. The new tracking system developed by the Office of Naval Research not only automated most of the tracking process but also largely replaced the need for the managers to use their dark matter to identify potential incorrect tracks. The new system greatly improved the capabilities to track the enormous number of ships that previously were tracked primarily by human operators. It also is capable of gathering additional information that makes use of managers' intuition about possible inaccurate tracking largely unnecessary.

However, the track process designers continue to require the presence of management to sign off on the accuracy of tracks while ensuring that the routine tracking process is carried out as expected. If management becomes complacent about its dark matter duties, it may assume that the new system is so accurate that management members need not waste their time trying to find the potentially inaccurate tracks.

Because dark matter activities involve prediction, the possible removal of this management dark matter capability must be considered seriously because one correct prediction—i.e., identification of an inaccurate track by management that was not caught by the new system—might lead to identification of a suspect ship that is carrying weapons of mass destruction. Dismissing management prerogatives embedded in its dark matter

capabilities by "automating" them must be carefully considered before leadership eliminates this capability.

Standard KVA and Delta Correlation Approaches

The cascading of management goals to lower levels of management, and eventually to the process level, represents the relative influence of managers on their organizations. This kind of influence takes time to become a reality at the process level. Because the response of the market to these kinds of goal-setting messages is uncertain, it is necessary to measure the change or delta in value (e.g., capabilities, revenue) of the organization over time as the goals eventually become, or fail to become, reality in process changes.

We must acknowledge the likelihood that these kinds of unique management activities do indeed influence organizational outcomes—as has been argued in prior research as well as in general business publications about the role and value of leadership and management. This assumption leads us to propose that changes in these activities should be roughly correlated with changes in market outcomes.

Because making a causal, one-to-one connection between dark matter messages and changes in core processes is problematic due to the semantic-interpretation problems mentioned earlier, we will not attempt to causally connect the two. Because a pure historical causal relationship cannot be established between the dark matter-market outcome-process change deltas, we will need to track the correlation among the three over time to better understand the relationship between deltas in management dark matter activity and the presumed corresponding deltas in market responses.

This logic leads to two measures of management dark matter activity. First, we can track the deltas in management's dark matter activity, process changes, and market outcomes over time. Second, using standard KVA methodology, we can account for the amount of dark matter outputs as a percentage of the total outputs of a process and, consequently, of the organization at a given historical point in time.[21]

As a first cut, we can aggregate the delta of all managers' dark matter activity and correlate it with market outcome deltas. Individual manager dark matter output deltas can be compared within the organization and correlated with the market outcome deltas to infer which managers have had the most influence on market outcomes. This approach extends standard KVA theory to the largely uncharted realm of how management influences organizational outcomes.

Basic Hypothesis

This formulation of the problem enables us to test some basic hypotheses about the correlation among dark matter outputs and organizational outcomes. One hypothesis would

[21] In the first case, we can use standard KVA methodology to allocate outputs and associated value (e.g., revenue, capability) to individual managers at a given point in time. In the second case, we can measure the relative changes in deltas among the managers' dark matter activity and the corresponding changes in market deltas.

be that there should be a much higher percentage of dark matter outputs in an open business environment (in which the OA approach is used to develop IWS systems) compared to a closed business model approach (in which proprietary IWS systems are developed).

Similarly, in the corporate sector, the amount of management dark matter produced over a given period of time should correlate with the amount of revenue generated over a period of time. It should follow that mature industries (e.g., petroleum extraction) that have largely mitigated risks and operate within a relatively stable environment in which demand is largely predictable should have less of this kind of dark matter than those operating within largely unstable environments (e.g., biotechnology).

The same would pertain to military environments in which there have been periods of stable competition (e.g., Cold War) among nations compared to periods when competition among entities is ill-defined and highly volatile (e.g., Global War on Terror). In the current, military environment in which there is greater instability, there is a larger need for the production of management dark matter to predict and deal with uncertainties and risks.

Hypothesis Test: ARCI versus Proprietary Acquisition

The ARCI case example provides a simplistic test of this hypothesis. We can compare the rough orders of magnitude estimates of dark matter outputs in both proprietary and open environments and then correlate these with the outcomes for development of IWS systems in both environments.[22] The hypothesis is that the OA, open-business-model environment of ARCI generated significantly more dark matter output than the proprietary model of system acquisition in IWS.

The hypothesis rests on the basic assumption that when managers are successful in setting and implementing goals to affect the markets within which they operate, markets respond positively and the converse is also true.

Through changes that they induce in their organization’s core processes, the commercial market responds by purchasing more of their products, the same number of higher priced products, or both outcomes. In the military “markets,” managers/officers use their dark matter to anticipate future actions by adversaries by adding capabilities and improving system acquisition cycle-times to respond to new events and competitor’s strategies.

However, when managers increase these kinds of creative activities and the result is lower revenue or reduced capabilities, it can be said that management reduced or failed to increase value. The delta in dark matter management activities from one period to the next, in response to anticipated changes in the market, should correlate to organizational performance over time.

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[22] It does not permit, however, the translation of deltas in dark matter activity over time into absolute numbers against which value can be allocated.

It does not follow, however, that merely increasing the number of dark matter activities (e.g., setting goals, trying to implement an increased number of goals) will result in increases in value. These goals and other creative management activities must eventually be translated into operational changes in core processes to affect any changes in company outputs and, therefore, responses to changes in the market. Such inevitability provides a rationale for counting management dark matter activities within counts of the total output of an organization at any given point in time.[23] Clearly, these activities are present and can be described with the standard KVA approach currently used to describe the outputs of all processes in common units. It follows that the standard KVA approach may be extended to triangulate with the correlational approach in estimating the effect of dark matter outputs on organizational outcomes.

ROI on Management Dark Matter

Using the KVA knowledge metaphor to describe outputs, the absolute total contribution of managing a process is equivalent to the total amount of knowledge required to produce and interpret all management messages during a given time period. The amount of time a manager (and supporting management technology) spends using this knowledge is the cost of management. It follows that a manager who must use a large amount of knowledge to process messages but can process those messages quickly, provides a relatively good return on investment in managing. Those who take longer to produce a similarly complex output cost more and provide a lower relative return on investment.

We would need to make a further separation of messages that involve use of dark matter from those that do not. Following this separation, we would estimate the amount of complexity in each message set using the learning time or other KVA approach, and estimate the total amount of output from the dark matter activity (i.e., the prediction-based messages). This resulting value would be included in the total output for a given period, and value would be allocated proportionately as is done currently in the KVA method for normal process outputs.

We can use standard KVA methodology to allocate outputs and associated value (e.g., revenue, capability) to individual managers at a given point in time.

Resolving uncertainty requires that managers make a prediction about what demands the future will make on current processes in terms of the amount and kinds of outputs required from those processes. These messages, interpretations of messages, and decisions about resolving risk and uncertainty can be observed over time such that it is

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[23] A very crude and simple test of this hypothesis would be to compare the dark matter job activities of the acquiring manager in a proprietary environment with the dark matter job activities of managers in an OA, open-management environment. The number of messages and complexity of messages used to coordinate acquisition in an OA, open-business-models environment would be much greater than for managers in the proprietary, single-vendor context. This would assume that the processes managed have about the same level of complexity. Relative complexity of the process becomes the index against which the amount of dark matter per unit of complexity is produced.

possible to gather historical data on the number and amount of complexity of these dark matter managing activities.[24]

So, in addition to the routine KVA data that estimates the number of common units of output from algorithmically definable processes, it also is possible to count the number of dark matter outputs and their respective complexity. The total amount of output, then, is a function of the number of times a given asset produces algorithmically defined outputs multiplied times the amount of complexity required to produce the outputs plus the dark matter outputs that occur in that given time period.[25]

Past research on the value of management and leadership provides a useful review of alternative approaches to this daunting problem. There are a number of lines of research that have attempted to address this problem indirectly and may offer some insights about its many varied aspects. Thus, it would be useful to review the strengths and weaknesses of these prior attempts to resolve this difficult problem.

Prior Approaches to Assessing the Value of Management

The literature on the value added by managing includes the effect of corporate governance on firm value, the drivers of value (including managing activities), the characteristics of great leaders, failures of management, and fund management.

This review of previous attempts to assess the value that management adds includes research on:

- How corporate governance affects a firm's valuation,
- What management characteristics can lead to improved company value,
- Fund-management approaches to solving the problem, and
- Attempts to solve the management value added quantification problem using a knowledge framework.

Corporate Management/Governance Value

The current literature discussing the effect of corporate governance on management valuation does not focus on direct valuation of individual managers or those in positions to

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[24] This formulation assumes that we do not count redundancy in the dark matter activities—such as exhorting the vendor to "work harder" every day during the observational time period. We would count the non-redundant or unique dark matter outputs. In this case, we might only count the exhortation to work harder as one output instead of one output repeated many times. We would also separate out the non-relevant activities—for example, when the manager calls his wife to arrange a dinner date.

[25] Given that there are many, if not infinite, alternative paths for the organization's future, it is impossible to enumerate all the potential opportunities foregone by selecting a specific path. It is, therefore, not useful (in accounting for dark matter outputs) to attempt to look backward to determine whether managers might have better utilized their dark matter to make "better" predictions. This type of interpretation must be left to the subjective judgment of the leadership of the organization.

perform management governance activities. Instead, the current literature revolves around two major themes: an analysis of corporate governance and its relation to firm value as well as an analysis of corporate management techniques and suggestions on qualitatively increasing management's value.

Literature focused on corporate governance/management focuses on two major themes: addressing whether corporate governance affects firm value and providing suggestions on how to qualitatively increase the value of corporate governance/management—thus, increasing firm value. Literature focused on the second theme generally does not relate techniques directly to quantitatively measured increases in firm value, but instead implies that the techniques will increase value in some way.

Corporate Governance and its Effect on Firm Value

Black, Jang, and Kim set out to answer the question: "How do a country's corporate governance rules, or the corporate governance practices of individual firms within a country, affect overall firm value and performance?" (Black, Jang, & Kim, 2003, p. 1). This study answers the question by developing a corporate governance index for 526 Korean public companies. The index is based on information obtained on shareholder rights, board of directors in general, outside directors, audit committee and internal auditor disclosure to investors, and ownership parity. It then uses multiple regression equations to explain the variance in the corporate governance index compared to firm value. The analysis finds evidence that corporate governance is an important factor in explaining the market value of Korean public companies. Following a similar model Beiner, Drobetz, Schmid, and Zimmerman (2006) establish a relationship between corporate governance quality and firm value.

Beiner, Drobetz, Schmid, and Zimmerman, in their work "An Integrated Framework of Corporate Governance and Firm Valuation," state that:

> Recent empirical research shows evidence of a positive relationship between the quality of firm-specific corporate governance and firm valuation. Instead of looking at one single corporate governance mechanism in isolation, [this report] constructs a broad corporate governance index and [applies] five additional variables related to ownership structure, board characteristics, and leverage to provide a comprehensive description of firm-level corporate governance for a representative sample of Swiss firms. To control for potential endogeneity of these six governance mechanisms, [the report develops] a system of simultaneous equations and [applies] three-stage least squares (3SLS). [The] results support the widespread hypothesis of a positive relationship between corporate governance and firm valuation. (2006, publication abstract)

This work shows a relationship between the quality of specific corporate governance practices and the value of a firm, but does not allow for direct valuation of individual managers. It primarily supplements the intuitive hypothesis that quality affects value.

Klein, Shapiro, and Young (2005) prove a similar relationship between quality and value in Canadian firms, but add the additional element of the ownership category. In their report, the researchers analyze the relationship between firm value and indices of effective

corporate governance in Canadian firms. "The results indicate that corporate governance does matter in Canada. However, not all elements of measured governance are important, and the effects of governance do differ by ownership category" (Klein, Shapiro, & Young, 2005, publication abstract). The results of this study establish the link between quality of governance and value.

An additional work with similar results is Hsiu-I Ting's (2006). In this work, Ting investigates the 207 IPO companies encompassing the Taiwan Security Exchange between the years 1992-2002. His analysis examines situations in which corporate governance could increase firm value.

> [Ting] finds positive effects of corporate governance on firm performance, which proves the existence of a corporate governance effect. Different from the previous studies, this paper addresses the fact that the corporate governance effect exists under poor economic conditions. As expected, firms with poor corporate governance mechanisms tend to perform badly when business cycles go downward. In other words, the report indicates the importance of corporate governance increases during poor economic conditions. Firms with higher agency costs also show a significant corporate governance effect. [Also, when investing more in other companies causes a firm structure to become more complicated while simultaneously diminishing information disclosure, the corporate governance mechanism could work effectively.] Finally, the recognition of a supervisor is an important factor for corporate governance effect as well. Firms with executive recognition appear to have a corporate governance effect. (2006, p. 8)

To summarize, this line of research demonstrated that there is a relationship between corporate governance firm values, but there is a profound gap in quantifying the precise value of the management that governs companies. Furthermore, once the management/government structure is broken down and one wishes to determine the value of specific managers, the lack of quantifiable value studies becomes even more accentuated. There is a lack of studies that attempt to measure the value of management in dollar terms.

Another theme of corporate management valuation studies involves discussing the methods of increasing the value of corporate management. Unfortunately for our purposes, this literature fails to produce objective measures of how much value managers add.

Increasing the Value of Corporate Management

There are many works discussing techniques to improve management techniques, and most offer useful insights to do so. However, these techniques are limited because there is no quantifiable measure to discover how they increase firm value.

All agree that more effective management is ideal, but seem to question how one can discover what management characteristics and techniques are the most effective without discovering the relative value they add. How can managers discover what they should place emphasis on without knowing the payoff? The following works all discuss valuable techniques crucial to manager success, but none supplement their advice with techniques to discover their actual value added.

In their book, *Value Driven Management: How to Create and Maximize Value over Time for Organizational Success,* Pohlman and Gardiner discuss how to increase management's value by focusing on eight "value drivers": external cultural values, internal cultural values, employee values, supplier values, customer values, third-party values, competitor values, and owner values. This guideline is structured to help managers keep pace with fluctuating business structures in order to achieve long-term success. Pohlman and Gardiner's book is about leading, managing and working in organizations as managers enter the twenty-first century. Its techniques are rooted in traditional theories and styles, but focus on value creation over time—because traditional theories must constantly make adjustments as paradigms shift.

Following in the same spirit is Michael Armstrong's *A Handbook of Management Techniques Revised*, 3rd edition. Armstrong's work acts as a guide for professional managers or as an essential guide for students. His work attempts to encompass value-adding skills/techniques for numerous management responsibilities. It distinguishes between tasks that fall into the following categories: marketing management, operational management, financial management, human resource management, management science, planning and resource allocation, efficiency and effectiveness. Within these topics, Armstrong's work includes 100 qualitative, systematic, and analytical methods used to assist in decision-making and to improve efficiency and effectiveness. As is evident, Pohlman and Gardiner as well as Armstrong focus on techniques that increase management's value. Gardner's work described below takes a slight shift in topic from suggesting useful techniques to highlighting character traits that are inherent in a successful leader.

John Gardner's *On Leadership* (1990) focuses on the characteristics a leader should possess, centering on managers and how such qualities increase their value to their business. Gardner lists six respects with which leader/managers distinguish themselves from the general run of managers:

- They think longer-term—beyond the day's crises, beyond the quarterly report, beyond the horizon.
- In thinking about the unit they are heading, they grasp its relationship to larger realities—the larger organization of which they are a part, conditions external to the organization, global trends.
- They reach and influence constituents beyond their jurisdictions, beyond boundaries.
- They put heavy emphasis on the intangibles of vision, values, and motivation and understand intuitively the nonrational and unconscious elements in leader-constituent interaction.
- They have the political skill to cope with the conflicting requirements of multiple constituencies.
- They think in terms of renewal. The routine manager tends to accept organizational structure and process as it exists. The leader or leader/manager seeks the revisions of process and structure required by ever-changing reality.

Management characteristics are obviously important to company success. Therefore, it clearly follows that company failure can result from choosing a manager that lacks the characteristics necessary for success. Gerard Egan, in *Adding Value: A Systematic Guide to Business-driven Management and Leadership*, cites this as one of the main reasons for organizational failure. He provides information on choosing the correct manager.

When companies fail, Egan proposes that true failure lies not with managers themselves, but with the system by which they are chosen and developed. Egan states that it is not wise to promote professionals to management without any guidance on how to actually manage; they may excel in a specific skills area, such as engineering or accounting, but may lack the specific management training necessary to be good managers. Egan describes the basic skills managers need to look beyond their own area of expertise in ways that add value to the business. He presents a comprehensive, integrated system of management that can be adapted to meet any company's real business needs—including strategy, leadership, structure, human resources, innovation, and organizational culture. Egan offers theoretical constructs as well as three practical, hands-on models. Most importantly, he shows how to integrate the models into a system that managers can use to identify, organize, and implement the best ideas emerging from today's "business and organizational potential" movement.

All the techniques on management characteristics discussed in countless books may be useful, but they do not address the issue of how much value such techniques and characteristics can add in specific instances with specific managers.

The Alpha measure in fund management attempts to grasp some idea of the value of management in general, but also has several limitations that make it problematic for use in determining the value added of individual managers.

Lessons from Fund Management Research

“Alpha” measures the difference between a fund's actual returns and its expected performance given its level of risk (as measured by “beta”). A positive alpha figure indicates the fund has performed better than its beta (risk) would predict. In contrast, a negative alpha indicates a fund has underperformed, given the expectations established by the fund's beta. Some investors see alpha as a measurement of the value added or subtracted by a fund's manager. There are limitations to alpha's ability to accurately depict a manager's added or subtracted value. In some cases, a negative alpha can result from the expenses that are present in the fund figures but are not present in the figures of the comparison index. In addition, alpha is dependent on the accuracy of beta: If the investor accepts beta as a conclusive definition of risk, a positive alpha would be a conclusive indicator of good fund performance. Of course, the value of beta is dependent on R-squared.

For Alpha vs. the Standard Index, Morningstar performs its calculations using the S&P 500 as the benchmark index for equity funds and the Lehman Brothers Aggregate as the benchmark index for bond funds. Morningstar deducts the current return of the 90-day T-bill from the total return of both the fund and the benchmark index. The difference is called the fund's excess return. The exact mathematical definition of alpha that Morningstar uses is listed below.

Alpha = Excess Return - ((Beta x (Benchmark - Treasury))

Benchmark = Total Return of Benchmark Index

Treasury = Return on Three-month Treasury Bill (Morningstar).

Aside from Alpha, there have been several previous attempts to quantify the contributions of management, but they have, as yet, failed to provide a means to quantify the actual value added by individual managers. More recent approaches have employed a knowledge-based metaphor to frame the problem.

Knowledge-based Approaches

Housel and Nelson (2005) attempted to quantify the contributions of management in aggregate using a knowledge-based framework. The general idea of their study was that by quantifying management's total accumulated education, experience, and time with a firm, it was possible to generate its weighting on the output of a firm.

The limitations of this approach were that it did not provide a means to quantify individual managers' contributions; it assumed that management's aggregated contributions were purely a result of its members' combined education, experience, and time with the firm, and such weightings were applied as a constant across core areas or processes of a firm. While useful as a first attempt to quantify the value added by management in aggregate, the general approach assumed away individual differences among managers in terms of the value they add to a firm; likewise, the weighting factor could not be directly tied to the outputs of a firm in a relatively unambiguous way.

Further, it would be quite possible for two firms to have nearly the same weighting factor for management with radically different profitability and productivity scores. A more precise methodology that can differentiate among individual managers based on their observable contributions to process outputs would resolve these problems.

Pavlou, Housel, Rodgers, and Jansen's (2005) research had implications for the potential value added by managing activities. They assumed that implicit knowledge, which is akin to the notion of the type of knowledge managers use in making creative decisions (i.e., dark matter outputs), could be accounted for in terms of the experience of employees (including line managers). As such, a simple algorithm to measure their years of experience would serve as an indicator of the amount of knowledge used to produce the outputs of creative problem solving. However, this study did not directly address the issue of the value added directly by creative managing (i.e., management dark matter) activities.

There is a substantial collection of literature regarding corporate governance, leadership characteristics, and fund management, among other things, which attempts to address directly or indirectly the issue of how to measure the value added by managing activities. Yet, there remains a lack of research that attempts to objectively quantify the value added by individual managers. Further, past approaches do not provide a way of structuring the problem such that this kind of objective measure can be derived and revenue or value can be allocated to individual manager's dark matter outputs.

This research gap is further accentuated by the current concerns over the transparency of corporate activity, which assists investors in making more informed decisions. Transparency would aid investors in understanding the rationale for compensation packages provided corporate executives. This call for transparency is particularly important for businesses in the United States, but likely applies to the rest of the business world as well.

The research reviewed leads to a common conclusion: firm governance, leadership characteristics, management knowledge and experience do affect firm valuation. Because firm valuation is ultimately a result of a firm's profitability or productivity over time, there is a direct relationship between firm valuation and profitability or productivity over time. The question remaining is, "How much do dark matter managing activities affect firm profitability?"

The prior research also provides qualitative recommendations for how individual managers can increase their potential value to the firm. However, there is no relatively objective quantifiable evidence available to tie given characteristics of great leaders directly to the actual profitability or productivity of a firm.

While promising, the Alpha measure (the term sometimes used as the measurement of value a manager contributes to a fund), is a theoretical measure, is difficult to estimate, and is seldom reliable because it is very difficult to operationalize. Given that there does not appear to be a relatively objective way to quantify the value added by individual managers, such a measure would be beneficial to both managers and investors alike.

An approach to estimating how much value managers add to an organization or fund would provide the kinds of performance data that might be used to reward value-adding managers while not rewarding those that perform poorly. This presumably happens today with existing performance-evaluation techniques. But often, these techniques appear very subjective. A more objective technique that ties performance directly to the firm's profitability/productivity, indicating how much of a firm's revenue can be allocated to given managers' activities, would provide a more convincing evaluation.

The same performance information might lead poorly performing managers to self-organize in a way that ensures they are in positions where their talents can be used in the most profitable, productive ways. Such measurement would also provide investors with the kind of performance data that would lead them to reward organizations in which value added by management benchmarks well within an industry segment while withdrawing support for firms in which management does not perform well.

The same phenomena should occur in non-profit organizations as well when relative productivity among organizations can be compared on an objective basis. The federal government with its stop-light (Red=poor performance, Yellow=needs-improvement performance, and Green=good performance) scorecard for the large federal agencies is attempting to accomplish this goal. However, these rather crude indicators do not allow for the objective quantification of agency productivity, let alone the performance of agency management.

What is needed is a method that provides a way to quantify individual managers' contributions using structural, analytic, and relatively objective techniques that would allow

comparisons among organizations. The method we proposed above promises to meet these criteria and will allow allocation of revenue to managing activities. This extension of the KVA framework allows the description of managing activities in common units. In addition, because managers produce, interpret and send messages through their networks, the method also accounts for these managing activities in a common descriptive language.

Options and Dark Matter

Many management decisions are constrained by legal or regulatory frameworks that severely reduce or virtually eliminate management's ability to examine alternative future pathways or options. If there are no options for managers to generate and from which to select, there is no purpose for dark matter activities.

However, where options exist, managers can take full advantage of their dark matter capabilities to help move the organization toward desired future states. The introduction of open business acquisition models using an OA system development framework promise to create more options for managers to achieve their objectives. To succeed in this new environment, managers will have to make more use of their dark matter to produce the kinds of outputs that truly serve their warfighting customers. Acquisition managers should be more free and motivated to use their dark matter capabilities to mitigate potential risks while taking advantage of upside opportunities to build better systems that will meet warfighters' changing requirements as they face a more uncertain environment.

On the other hand, if acquisition managers follow management practices that lead to proprietary, non-collaborative solutions, their number of options (and, thus, the requirement for the use of their dark matter) are reduced. This, in turn, could lead to a reduction in warfighting capability compared to situations in which OA and open business models are employed, in which management dark matter can be more easily utilized by acquisitions management.

Framing these options using the real options analysis method is one way to structure managers analysis that also takes advantage of KVA data. This technique has the potential to provide managers a way to achieve more consistent results or organizational outcomes over time. Such techniques as real options and KVA can support managers in producing more informed dark matter outputs that will lead to better outcomes over time.

Benefits of Measuring the Value Added of Management

This method for measuring the performance of managing activities provides a variety of new kinds of information for executives, investors, and managers. These include:

- a method to test the value of different management techniques (including those advocated in prior research)
- information that investors could use to determine the performance of managers
- new ways to determine a salary or reward system based on managers' verifiable contributions

- a basic return on management (ROM) measure at any level of aggregation in an organization
- performance feedback to motivate managers to best utilize their individual talents/strengths

This new information would allow Adam Smith's *invisible hand* of the competitive market place to manifest itself in determining manager rewards and would allow managers to concentrate on techniques that are proven to increase their value.

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Appendix A. Future Research—The Delta Problem

The ultimate goal of the approach is to allocate some amount revenue to amount of management dark matter of outputs. This will become more likely when we have the derivative (coefficient) necessary to convert the dark matter correlational deltas to absolute numbers. The delta will be proportional to revenue with a given coefficient (that is yet to be discovered), once the coefficient is established.

Example of the problem:

Al Smith, manager of X process, generated 1Gigabyte of (relevant) dark matter based messages during January. In February, he generated 2 Gigabytes of dark matter messages. In March, he generated .5 Gigabytes of dark messages. In January, the company made $100 in revenue, in February it made $400 in revenue, and in March it made $200 in revenue. Correlating Al's amount of dark matter messages per month with revenue per month we establish a relatively negative correlation between the two values. We can then check the volatility of the company's revenue performance and Al's dark matter messages over the same 3 months and correlate these volatilities. Now we have 2 correlations: between revenue and Al's amount of dark matter messages and between volatility of revenue and volatility of Al's amount of messages per month. The correlation coefficient between the two would allow us to eliminate the dark messages that are not related to the revenue. We would then be able to predict the manager's activities based on changes in revenue or vice versa.

We need to establish the percentage of relevant (i.e., dark matter based) to irrelevant manager messages for every time period in terms of dark matter outputs. The volume of irrelevant messages should be independent of the prior time period. The amount of irrelevant messages is independent from revenue; the correlation of relevant messages to revenue should be very high when a manager is influencing corporate outcomes. The correlation between relevant and irrelevant messages also should be very low.

These basic conditions can be tested in empirical research. The results of the research should help us establish the coefficient that will allow us to translate correlational deltas into absolute numbers so that revenue can then be allocated to dark matter outputs.

Appendix B. Correlating the Delta in Value and Management Dark Matter Activity

Once the problems of establishing a method of bifurcating relevant and irrelevant dark matter messages has been resolved, it will be necessary to provide the method for relating changes in dark matter activity with changes in value (e.g., revenue, capability). To do this, we would have to establish a baseline dark matter measure for each manager

against which to calculate the rolling averages to generate the delta estimates. The corresponding time periods deltas would also be calculated to enable the correlations. Over time with a large sample size, it will be possible to estimate the optimal number of dark matter messages for a given level of environmental, market uncertainty.

Assumptions and Algorithms

In what follows, we lay out the basic algorithmic framework and assumptions for estimating the correlation between the management dark matter delta and value (e.g., revenue, capability) delta.[26] This approach will assume a conservative semantic interpretation that would permit estimation of amount of dark matter outputs in common units. The following algorithms are a preliminary attempt to describe the delta correlation approach.

The basic equation that accounts for all of the outputs of an organization at a given point in time is:

N (i.e., number of firings of a process, activity) x A (i.e., amount of complexity for one firing) + M (i.e., relevant dark matter management activity). Stated more simply:

N x A + M = Total Value (T)

To measure the change in this equation from time period 1 to time 2, it is possible to compute the total value produced in T_1 and subtract that from the total outputs in T_2 in the following equation:

Total value time period (T_1) = $N^1 \times A^1 + M^1$

Total value time period (T_2) = $N^2 \times A^2 + M^2$

The delta for value over the two time periods can be stated as:

$(N_1 - N_2) \times A + (M_1 - M_2) =$ delta in value resulting from dark management activities.

$$\underline{N^2 - N^1} \qquad \underline{(M^2 - M^1)} \quad \text{corresponds to} \quad \rightarrow \quad \underline{R^2 - R^1}$$

$$A^1 \quad (N^2 - N^1) \quad \mathbf{x} \quad \mathbf{A} \; \mathbf{+} \quad (N^2 - N^1) \quad \text{corresponds to} \quad \rightarrow \quad N^2 - N^1$$

$$\underline{\mathbf{(M_4 - M_3)}} \rightarrow \underline{\mathbf{(R_4 - R_3)}}$$

$$A \; + \quad (N_4 - N_3) \rightarrow (N_4 - N_3)$$

$$\underline{M - M^3} \; \_\_\_ \; \underline{M^2 - M^1} \rightarrow \underline{(R - R^3)} \; \_\_ \; \underline{R^2 - R^1}$$

$$N - N^3 \qquad N^2 - N^1 \rightarrow (N - N^3) \qquad N^2 - N^1$$

The degree of change from one period to the next resulting from this dark management activity should correspond to the change in value (e.g., revenue, capability) from the same two time periods. This equation can be stated as follows (where V = revenue or capability):

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[26] The approach is incomplete at this juncture because we do not have the coefficient that would allow us to derive an absolute number (i.e., in common units of output) that would lead to allocation of value to management dark matter activity.

$$A_1 (N_2 - N_1) / (N_1 - N_2) \times A + (M_2 - M_1) / (N_2 - N_1) \rightarrow (V_2 - V_1) / (N_1 - N_2)$$

The above formulation assumes that we have separated out irrelevant messages from M and that M represents relevant messages. It also assumes that management messages that can be found in the outputs of current processes are algorithmically definable and, therefore, accounted for using the routine KVA methodology. This formulation assumes that redundant messages have been eliminated to prevent over-estimation of M. This formulation also assumes that it is possible to derive all estimates from historical data.

Appendix C. Observations about Over-estimates of Dark Matter

Our formulation of the effect of management dark matter activities on organizational value can lead to some interesting observations about managers who generate dark matter activities that may not contribute to organization value. For example, when the change in value is 0, the corresponding change in M should also be 0. Managers whose generation of dark matter messages do not correlate with organizational performance may be creating a lot of “churn” but little value. Given a large number of time periods, the manager whose dark matter messages do not correlate with organizational performance would be seen as one who was not providing unique management contributions that had an impact on organization’s value-generating capabilities.

This formulation does not reward redundancy in management dark matter messages. For example, the manager who issues the command, “Work Harder!” everyday for a given time period would only get credit for one message because the following “Work Harder!” messages would be redundant with the first. Only new and unique messages would be counted in the total M for this given manager.

This formulation also would lead to the conclusion that management dark matter would have little influence on organizational value generation when the organization was operating in a very stable environment with little risk or uncertainty. There should be a corresponding increase in management dark matter activity when an organization encounters turbulence, risk, and even higher opportunities for increased value. It follows that the complexity of a management environment increases in correspondence with increases in environmental uncertainty or risk, and the amount of dark matter messages should also increase correspondingly in response. For example, instructing an employee to “paint the door green” in routine operations is much less complex than trying to predict how the market will respond to green doors as tastes change. Similarly in the military environment, an officer’s instructions to move supplies from point A to point B in peace-time would be less complex than in war-time, when there are increasing risks and uncertainties that must be dealt with.

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Wednesday, May 16, 2007 1:45 p.m. – 3:15 p.m.	**Panel 6 - Contracting for Support of Military Operations**
	Chair: **RDML Kathleen Dussault**, USN, Deputy Assistant Secretary of the Navy (Acquisition) **Discussant:** **Jeffrey P. Parsons**, Director of Contracting, Office of Command Contracting, Headquarters, US Army Materiel Command **Papers:** ***Contractors on the Battlefield: When and How? Using the US Military's Risk Management Framework to Learn from the Balkans Support Contract*** **Victoria A. Greenfield**, US Naval Academy and **Frank Camm**, RAND Corporation ***Contractors Supporting Combat Operations: A Failure of Imagination*** **Richard L. Dunn**, University of Maryland

Chair: RDML Kathleen Dussault, USN, Deputy Assistant Secretary of the Navy (Acquisition), received her commission from Officer Candidate School in Newport, Rhode Island, in November 1979. She graduated from the University of Virginia in 1977 with a Bachelor of Arts in American Government. Upon graduation from Navy Supply Corps School in May 1980, she was assigned as Assistant Supply Officer and Disbursing Officer to the Navy Communications Station, Nea Makri, Greece. In October 1981, Rear Adm. Dussault was assigned as Supply Officer in USS POINT LOMA (AGDS-2), the Pacific Area Launch Support Ship for the Trident missile program.

In June 1984, Rear Adm. Dussault was assigned to Defense Contract Administration Services Region (DCASR), Los Angeles. In 1986, she transitioned to duties as a negotiator and Contracting Officer at Naval Supply Center, Oakland, California. During this tour, Rear Adm. Dussault completed a Master's Degree (with honors) in Procurement Management from Saint Mary's College in Moraga, California. In 1990, Rear Adm. Dussault was assigned in USS CONCORD (AFS-5) as the Assistant Supply Officer where she performed two deployments contributing to the logistics success of Operations Desert Shield and Desert Storm.

In October 1993, Rear Adml Dussault reported to Naval Air Systems Command (NAVAIR) where she performed duties as Procuring Contracting Officer for the Sidewinder 9X new development program. In 1995, she served as the Business and Financial Manager for programs managed by the Space and Naval Warfare Command. In June 1997, Rear Adm. Dussault served as the Executive Assistant to the Deputy Assistant Secretary of the Navy for Acquisition Management within the office of the Assistant Secretary of the Navy for Research Development and Acquisition. In August 1998, she entered the Industrial College of the Armed Forces and received her Master's Degree in National Resource Strategy in May 1999. Rear Adm. Dussault reported as

Supply Officer of USS SEATTLE (AOE-3) in August 1999 where she served as Afloat Logistics Coordinator while deployed to the Fifth Fleet operating area. In May 2001, she assumed command of Defense Distribution Depot San Diego, California. In April 2003 she assumed command of the Office of Special Projects, Arlington, Virginia.

Over the course of her career, Rear Adm. Dussault has achieved the highest levels of certification in Acquisition and Financial Management as well as Joint Professional Military Education. She also completed the Executive Education Program at Columbia Business School. Her decorations include the Defense Superior Service Medal, Legion of Merit, Navy Meritorious Service Medal with two gold stars, Joint Service Commendation Medal, Navy Commendation Medal, Navy Achievement Medal with gold star, and various unit citations, campaign medals and service medals.

Contractors on the Battlefield: When and How? Using the US Military's Risk Management Framework to Learn from the Balkans Support Contract[27]

Presenter: Victoria A. Greenfield, PhD, holds the Crowe Chair in the Economics of the Defense Industrial Base at the US Naval Academy where she has developed an upper-level undergraduate course, "The Economics of the Defense Industrial Base," and leads a capstone research seminar. She conducts research on defense-industry structure, privatization and outsourcing, and globalization; international narcotics markets; and international trade. She has published recently on risk management in military contracting; the role of contractors on the battlefield; technical trade barriers facing US exporters; defense aerospace globalization; narcotics trafficking; and replacement policies for aging aircraft under uncertainty. Dr. Greenfield's other research has focused on strategic planning and performance measurement for federal agencies.

Prior to joining the Academy, Dr. Greenfield held the positions of Senior Economist, RAND Corporation; Senior Economist for International Trade and Agriculture, Council of Economic Advisers, Executive Office of the President of the United States; Chief International Economist, Bureau of Economic and Business Affairs, US Department of State; and Principal Analyst, Natural Resources and Commerce Division, Congressional Budget Office. Dr. Greenfield has advised senior US policymakers on wide-ranging domestic and international issues, including China's WTO entry, the UN Framework Convention on Climate Change (member of US delegation), the US-Japan civil aviation trade agreement, and farm policy under NAFTA.

[27] This paper draws from Greenfield, V.A., & Camm, F. (2005). Performance and risk management in the Balkans Support Contract (MG-282-A). Santa Monica, CA: RAND, which can be found in its entirety at www.rand.org/pubs/monographs/MG282/; a related presentation developed by Victoria A. Greenfield for "Contractors on the battlefield: Learning from the experience in Iraq," held at The George Washington University on January 28, 2005, and a paper presented at a conference of the American Bar Association on March 3, 2006. We thank the sponsors of the originating RAND report; however, we bear sole responsibility for all errors or omissions and for the views expressed in this paper, which are our own and do not reflect those of our employers or the research sponsor.

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Abstract

For centuries, the US military has wrestled with decisions about when and how to use private contractors, especially "Contractors on the Battlefield." Reports of mixed performance, inexperienced contracting officers, miscommunication, and profiteering date back to the Revolutionary War. History may be "living history," in part, because

decision-makers have lacked adequate means of systematically anticipating future outcomes and harvesting lessons from the past. The US military's risk-management framework, a familiar tool in other operational settings, may fill that void. To illustrate, this paper applies the framework to the Army's Balkans Support Contract (BSC); the contract covers a variety of life support, transportation, and maintenance services and has registered a substantial track record in deployment. The application demonstrates the utility of the risk-management framework and draws general lessons from the BSC experience for selecting service providers and for contract development, management, and oversight. Four deceptively simple lessons emerge from the analysis: first, not all risks are inherently contractual; most are environmental or activity-based. Second, risk is dynamic; appropriate responses change over time. Third, a contract is only as good as its customer; design and execution determine outcomes. And fourth, risk management is not risk elimination; not all risk can or should be eliminated.

Introduction

For centuries, the US military has wrestled with decisions about when and how to use private contractors, especially "Contractors on the Battlefield." Under what circumstance should it hire contractors and, if it does hire them, what can it do to insure that it gets what it wants, when it wants it, at a reasonable cost?

Shrader (1999, p. 3) describes the use of contractors in the Revolutionary War and the apparent timelessness of the Army's experience:

> The Army experience with private contractors in the War for Independence contained most of the elements which would characterize the later use of contractors on the battlefield: mixed results in terms of performance and adequate support for the troops; lack of experience and expertise on the part of Army officers in dealing with contractors; lack of clarity in communications between the Army and supporting contractors as to requirements, capabilities, and costs; and financial manipulation and desire to increase profits at the expense of the Army on the part of contractors.

Much of what Shrader describes rings true today, but why? History may be "living history," in part, for reasons of resources and culture, e.g., the number of billets allocated to contract oversight and the relative status of contracting officers, and, in part, for reasons of analytical capability: decision-makers have lacked adequate—both tractable and broadly applicable—means of systematically anticipating future outcomes and harvesting lessons from the past. A prospective analysis would enable planning, and a retrospective analysis would enable evaluation.

The US military's risk-management framework, a familiar tool in other operational settings, offers one possible means of filling the analytical void: it is simple and easy to use and can be replicated under wide-ranging circumstance. The framework consists of a 5-step continuous risk-management process—(1) identifying hazards, (2) assessing hazards, (3) developing controls and making risk decisions, (4) implementing controls, and (5) supervising and reviewing—and a complementary risk-assessment matrix. Decision-makers can use the framework to recast "when" and "how" in terms more amenable to systematic analysis: what risks does contracting present; how do they compare to the risks involved in using US military, host nation, or other support; and how, if at all, can any or all of those risks be mitigated—and at what cost?

To illustrate, this paper applies the risk-management framework to the Army's Balkans Support Contract (BSC). With particular attention to hazard identification and assessment, the application demonstrates the utility of the framework and draws general lessons from the BSC experience for selecting service providers—of different types—and for contract development, management, and oversight.

We chose the BSC because it covers a variety of life support, transportation, and maintenance services, and it has registered a substantial track record in deployment. Prior to the war in Iraq, it was also the largest contract of its kind, both in terms of dollars and contract staff. Among its limits as a case study, the BSC does not cover all types of services—it does not, for example, provide weapon system support.

In the sections that follow, we review the origins, principles, and structure of the BSC as the basis for analysis, present and apply the US Military's risk-management framework, and summarize our findings.

BSC Origins, Principles, Structure, and Participants

The BSC, as described in this paper, began operating in 1999, but can trace its roots to the first Logistics Civil Augmentation Plan (LOGCAP) contract, which the Army awarded to Brown and Root Services, now Kellogg Brown and Root (KBR), in 1992.[28] The Army established LOGCAP as a performance-based, indefinite-delivery-indefinite-quantity (IDIQ), pre-planned umbrella contract, capable of delivering a wide range of services worldwide, in contingencies or crises, on demand. Flexibility and responsiveness are central concepts in LOGCAP and other such contracts.

- A performance-based contract tells the contractor what the customer wants done, but does not tell the contractor how to do it. The contractor is free to leverage its resources, including expertise.
- An IDIQ contract does not specify the delivery date or exact quantities at the time of the award; instead, the customer orders services and work under the contract, as needed. This level of generality can accommodate uncertainty about timing and quantities.
- In a pre-planned contract, the contractor develops an implementation plan for a future contingency, ideally in close collaboration with the customer. The plan should cover all activities posited in the statement of work, potentially reducing turnaround times on service and work orders.

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[28] The BSC is now in its second iteration; the first, as described in this paper, expired in 2004. On June 21, 2005, the Army awarded a re-specified firm-fixed-price and cost-plus-award-fee contract to KBR for a 5-year term; the Army solicited 66 bids on September 29, 2003, and received three. The contract's spending limit is $1.25 billion. (For more information, see www.defenselink.mil/contracts and Halliburton (2005) at www.halliburton.com.) This paper addresses the terms of the BSC as established in 1999 and modified over the primary period of research encompassed in Greenfield and Camm (2005), i.e., 2001-2003. For a much more detailed treatment of the contract, see Greenfield and Camm (2005), which draws material from: CETAC (1998), CETAC (1999), CETAC (2001), and CETAC (2002); CETAC-OC (1997); Kolar (1997); McElroy (1999); USACE (1994); Wynn (2000); and others. For a particularly readable overview of the contract and the roles of its participants, see Wynn (2000).

- An umbrella contract covers a broad range of activities, hence the term "umbrella," but the customer can choose to turn to other service providers on a task-by-task basis as it sees fit; indeed, under certain circumstances the customer must consider using other providers, including other contractors, US military personnel, and host-nation support.

The Army activated the LOGCAP contract in the Balkans in 1995. In 1997, the Army replaced the Balkans element of the LOGCAP contract with a sole-source contract and, almost two years later, the Army awarded the BSC in an open competitive process based on "best overall value." The selection factors for the BSC award consisted of: the management execution plan, the contractor's experience, the contractor's past performance, and cost (CETAC, 1998). The cost factor spoke to realism, completeness, and financial capability, but not directly to level. The selection process weighed all non-cost factors equally—together, they were deemed "significantly more important" than cost—and considered performance risk for all four factors.

The principles and structure of the BSC closely mirror those of the original LOGCAP contract and impart similar flexibilities to both the customer and the contractor. The BSC is also a performance-based, IDIQ, pre-planned umbrella contract. As such, the contract confers an opportunity, but not an obligation to obtain life support, transportation, and maintenance services. The performance-based work scope tells the contractor what needs to be done, e.g., that the Army requires laundry, food, waste removal, road repair, or other services, but it does not tell the contractor how many people or what type of equipment to use.

And, as was true of the LOGCAP contract, the BSC is also a cost-plus-award-fee (CPAF) contract.

The CPAF payment structure warrants further consideration, especially with regard to the incentives it creates for cost control and cost inflation. The bases for award-fee calculations, cost reimbursement, and future contract awards each play a part in determining those incentives.

First, award-fee payments are calculated on the basis of negotiated estimated costs, not actual costs, and they depend on the results of regularly scheduled performance evaluations. In the BSC, the contractor may obtain an award-fee payment of up to 8% of the negotiated estimated cost, depending on its performance rating. If, for example, the contractor receives a perfect score in a performance evaluation and the estimated negotiated cost of the service it provides is $100, then it would receive an $8 award-fee payment; if the estimated negotiate cost is $50, it would receive a $4 award-fee payment; and so on. If it receives a less-than-perfect score, it would receive a pre-determined fraction of the $8 or $4 award-fee payment.

If actual costs differ from estimated costs, the award-fee payment will only change if the difference affects the contractor's performance rating, which would depend, in turn, on the specification of the performance-evaluation criteria. If cost is among the criteria, the contractor might obtain a higher rating (and payment) for lower costs and a lower rating (and payment) for higher costs. The BSC criteria have to varying degrees addressed cost, quality, coordination, flexibility, and responsiveness.

Second, CPAF means that the Army reimburses only those costs that are "reasonable," "allowable," and "allocable" under the contract (Wynn, 2000, p. 6). The

Army must approve the expenditure. If the contractor spends above and beyond the cost estimate, the contractor may not get that approval. Moreover, even if the contactor gets the approval, it may, as already noted, obtain a lower rating in its performance evaluation, which would, in turn, result in a lower award-fee payment.

Third, if the contractor develops a reputation for inflating costs; that is, spending above and beyond the negotiated estimated costs, the Army might not view it favorably in future competitions for other contracts.

Together, these three considerations suggest that, once the customer and contractor have finished negotiating the cost estimate, the CPAF structure provides little or no incentive to inflate cost, could provide incentive to control cost, and may even provide incentive to reduce costs, if reductions result in higher performance ratings. Inflating cost will not generate more award fee; indeed, it may result in less fee and fewer future contract awards. However, tensions may arise when quality is also a criterion, particularly if additional spending can improve the quality of service.[29] Higher costs, all else constant, might result in a lower performance rating, but higher quality, all else constant, might result in a higher rating. The contractor's response to these competing incentives would depend on their relative weights and net effect in the evaluation process, which would also depend on the preferences of the customer.

Ultimately, the CPAF structure places the burden on the customer to clearly establish and articulate its needs and preferences in developing the contract, to scrutinize the contractor's plans, to firmly negotiate appropriate cost estimates, to closely review actual costs when the contractor presents them for approval and reimbursement, and to uphold its preferences in the performance-evaluation process. The analysis of the BSC that follows confirms each of these points in part or whole.

Finally, the contract's participants constitute a near "cast of thousands," spanning the globe, contributing a range of talents, skills, and other resources, and representing diverse and sometimes conflicting interests. For example, US Army Europe in Germany is the bill-payer; the operational units deployed in the theater are among the end-users; the US Army Corp of Engineers in Winchester, VA, provides the Principle Contracting Officer (PCO); and the contractor, KBR in Houston, TX, provides service. The Defense Contract Management Agency and the Defense Contract Audit Agency also provide substantial administrative support. Notwithstanding several foregoing references to "the customer" as if it were a single monolithic entity, the interests of the bill-payer, end-users, PCO, and others are not necessarily the same and at times may be at odds with one another. In particular, end-users may want more or better service from the contract and the bill-payer may want lower cost, leaving the PCO to address resulting frictions.

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[29] Economists would also note two other considerations: first, the possibility of low-balling in the negotiation to win the award, with the intent to charge actual, higher costs later; and, second, the possibility of inflating costs in the current period to increase the value of contracts in later periods. In the first instance, issues of reimbursements and award-fee determinations could discourage low-balling. In the second instance, another factor would come into play, i.e., the potential for future gain. The contractor would need to assess the effect of its current behavior on the likelihood of winning a future contract and weigh the possible sacrifice of current earnings, e.g., through loss of reimbursement or award-fee payment, against the value added to future contracts, appropriately discounted.

Given the PCO's "location" between the end-users and the bill-payer, he or she may have a strong interest in minimizing those frictions.

The Risk-management Framework

Army and joint doctrine (Department of the Army, 1998; Department of the Army, Marine Corps, Navy, & Air Force, 2001) provide a risk-management framework that can be used to identify hazards, assess their probability and severity, establish risk-mitigation measures or risk controls, and compare risks and potential responses across alternative service providers.[30] The framework consists of a 5-step continuous risk-management process and a complementary risk-assessment matrix. The doctrine focuses on tactical and operational considerations, but refers to other applications, including contracting. Discussions with Army and other military personnel suggest that the underlying concepts are ingrained in their thinking about deployment generally, but not in their thinking about the use of contractors specifically.

The Army[31] defines *risk* as the, "chance of hazard or bad consequences; the probability of exposure to chance of injury or loss from a hazard; risk level is expressed in terms of hazard probability and severity" (Department of the Army, 1998, p. Glossary-2). The Army further defines *hazard* as, "a condition or activity with potential to cause damage, loss, or mission degradation" and any actual or potential condition that can cause injury, illness, or death of personnel; damage to or loss of equipment and property; or mission degradation (Department of the Army, 1998, pp. Glossary-1 and 2-2).[32] In loose, non-technical terms, "bad things" can happen in a field operation or elsewhere, with varying degrees of likelihood and impact.

The 5-step risk-management process unfolds as follows:

First, "Identify hazards" by analyzing the mission, listing possible hazards, and listing their causes. This step is forward-looking: for example, a hypothetical planner faces concerns about a service provider's performance, e.g., will food be cold or roads impassable (see the discussion in the following section). The planner identifies specific "bad things" and, perhaps as importantly, their causes. Failure to identify the causes—especially the sometimes less obvious root causes—could lead a planner to suggest the wrong type of risk control, which could either leave the risk unchecked or create additional risk. An assertion that "bad things can happen" won't suffice.

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[30] Greenfield and Camm (2005) offer a more detailed treatment of risk, the risk-management framework, and the applicability of the framework.

[31] The Army (1998) and joint (2001) doctrine each make use of slightly different vocabulary in their discussions of risk; this analysis draws primarily from the Army doctrine.

[32] Department of the Army (1998, p. ii) defines "mission" as including "mission, operation, or task."

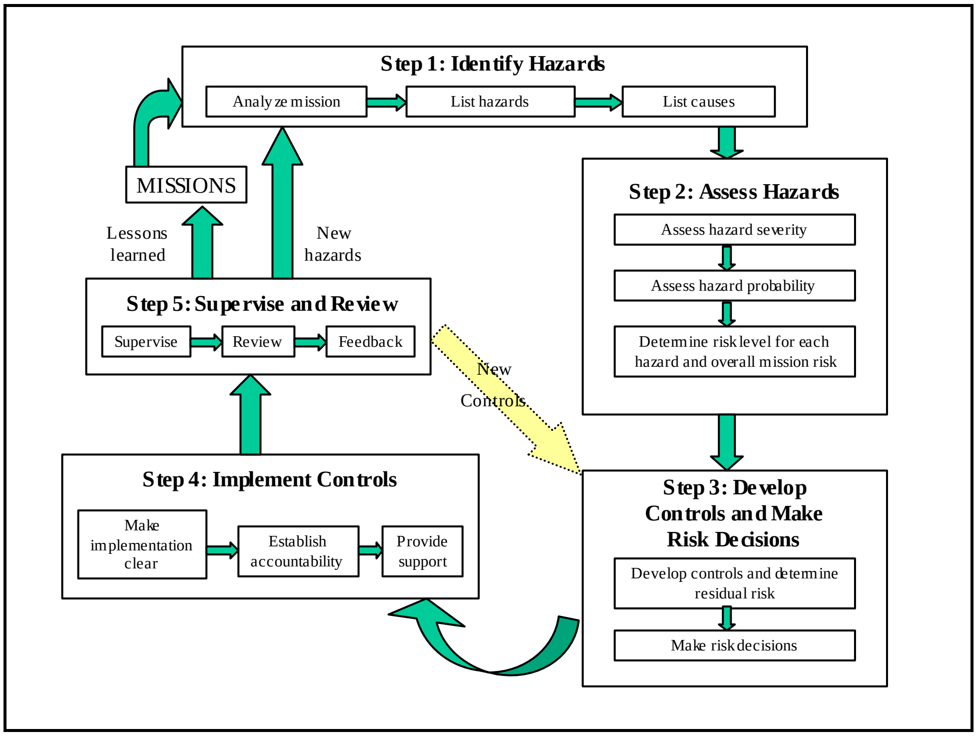

Figure 1. A 5-step Continuous Risk-management Process
(Department of the Army (1998); Department of the Army et al. (2001))

Second, how likely is it that the "bad things" will happen and how bad are they? This step, assessing hazard probability and severity, can be used to establish priorities for allocating resources and, speaking to the issue at hand, determining whether or not a contract is an appropriate vehicle. As shown in Figure 2, Army doctrine provides a simple matrix for addressing the issues. Third, develop controls and make risk decisions. With a reasonable understanding of the hazards and their potential consequences, the planner can develop controls, determine residual risk, and make risk decisions. The process instructs the planner to make decisions about how much risk to accept, implying that it may not be possible or appropriate to eliminate all risk. Fourth, implement controls in the operating environment and, if possible, before entering the operating environment. Fifth, supervise and review the process and develop new controls. This step enables continuous feedback. At this stage, it may be helpful to re-invoke steps one and two to review any realized hazards—what "bad things" have actually happened, what caused them, and how bad are they?

Risk Assessment Matrix						
		Probability				
Severity		Frequent A	Likely B	Occasional C	Seldom D	Unlikely E
Catastrophic	I	E	E	H	H	M
Critical	II	E	H	H	M	L
Marginal	III	H	M	M	L	L
Negligible	IV	M	L	L	L	L
E—Extremely High Risk H—High Risk M—Moderate Risk L—Low Risk						

Figure 2. Risk-assessment Matrix: How Likely and How Bad?
(Department of the Army (1998); Department of the Army et al. (2001))

The BSC in Theory and Practice

This section focuses on applications of Steps One and Two of the 5-step process: first, in a prospective assessment of underlying hazards in the BSC; second, in a retrospective assessment of the contract's performance.

Underlying Hazards

Two broad categories of hazards emerge from a review of the BSC work scope and its operating environment. One category relates to the performance and cost of day-to-day activities, such as food preparation, laundry, road repair, and waste removal; the other to higher-order concerns about mission success, force management, and safety and security.[33] Context matters. Faulty road repairs may delay a postal delivery in one instance and prevent troops from reaching the battlefield in another.

Framed in terms of the risk-assessment matrix in Figure 2, a planner might rank most day-to-day hazards as negligibly or marginally severe and most higher-order hazards as critically or catastrophically severe.

In some instances, hazards across and within categories are interrelated. For example, seemingly minor day-to-day problems can give rise to higher-order concerns over time. If quality-of-life suffers, e.g., if food is cold, laundry is dirty, and latrines overflow, the Army may have difficulty recruiting and retaining troops. Moreover, if the

[33] Mission success includes readiness.

costs of these services are too high,[34] the Army may eventually run short of funding for other mission-essential activities. Hazards may also involve trade-offs between competing objectives, especially cost and quality. Typically, the customer must pay more to get more, sometimes, as already noted, causing tension and friction among contractors, bill-payers, end-users, and PCO's.

Categorizing and recognizing relationships among hazards is important to understanding the nature of risk; but drilling down to underlying causality yields equally important insight for developing risk controls.

Consider an anecdotal example: a soldier returns from a late shift, cannot get a hot meal, and complains. The immediate hazard is the lack of a hot meal, but what is the cause? The most obvious answer might be, "a closed kitchen," possibly because the contractor is short staffed, but the terms of the BSC point elsewhere. The BSC directs the contractor to "Provide 24-hour food service operations"; however, it also calls for "limited food service during non-meal hours" (CETAC, 1998). As such, the contract does not require hot meals after the late shift. It permits and arguably directs the opposite. In this case, the "cause" is the underlying statement of work. The customer is getting what it asked for, nothing more and nothing less.

Had the analysis ended with a closed kitchen or short staffing, a planner—or reviewer—might have suggested the wrong control, perhaps a staffing mandate, which might have increased cost, but would not have solved the problem.

As this example suggests, one possible source of hazard is the contract itself or, more accurately, a poorly framed statement of work. On this basis, it might be tempting to argue for eliminating the contract—if the contract is the source of the hazard, why not eliminate the contract? Merely shifting to another provider, e.g., a US military provider, will not resolve the problem if the customer continues to misstate its needs; moreover, shifting from contract personnel to troops could reduce the availability of troops for other activities that only they can perform.

Framing can be made better or worse with performance standards. In a performance-based contract, such standards do not specify "how"; rather, they clarify "what" and, ideally, provide an objective basis for evaluation. Without standards, the contractor may substitute its own or other commonly accepted standards and may provide the wrong service or the wrong amount of service. However, if standards are overly prescriptive they may negate intended flexibility.

A lack of performance standards may also contribute to so-called gold-plating, in which a contractor provides better or more service than is necessary at a higher cost. But, gold-plating cannot occur without willing participants on both sides of the contractual table. A CPAF contract might create incentives to over-provide by rewarding higher-quality service with a higher performance rating, but the customer must approve the contractor's plan, negotiate the cost estimate, and authorize reimbursements for actual costs. Ultimately, it takes two—or more—to gold-plate effectively.

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[34] Separate from concerns about intentional cost inflation, realized costs might be higher than expected costs within the confines of "reasonable, allowable, and allocable."

Other possible sources of hazard include ambiguous roles and responsibilities and inadequate communication and coordination. For example, a contract that calls for weekly deliveries of fuel oil should specify whether the contractor or the customer is providing the fuel, the truck, or the security. If the customer is providing any of these goods or services, it must be aware of and plan for its commitment; moreover, the customer must communicate with the contractor and vice versa, e.g., regarding timetables and whereabouts, to coordinate activities.

More recently, attention has turned to two other issues involving “roles and responsibilities,” those of chain of command and protections under international law. Contractors operate through the contracting chain of command and outside the military chain of command, which has raised concerns about responsiveness in the field; in some circumstances, their standing under international law is uncertain, which has raised concerns about their security.[35]

BSC Performance

Realized hazards under the BSC have involved day-to-day activities, with unsatisfactory outcomes arising from poorly stated service or work orders, inadequate communication and coordination, and incentives to accept higher costs in exchange for higher quality. Higher-order concerns have not borne fruit.

A GAO[36] report (2000a) on controlling costs in the BSC describes an instance in which planned firefighting services would have been too costly and potentially unsupportable, but available evidence strongly suggests that a lack of performance standards and communication between the customer and contractor contributed to the conflict. Concerns about unnecessary redundancy in power generation also seem to have had their roots, at least partly, in standards and communication issues. The GAO report also suggests instances of gold-plating. It describes spending on base camp personalization, e.g., changing street names for each new rotation of troops.

Another GAO report (2000b) issued at about the same time finds a high level of customer satisfaction with services under the BSC. The concurrent release of the two GAO reports—one criticizing spending and the other praising quality-of-life—calls to mind the inherent tension between cost and quality. The two reports address different costs and qualities, but the juxtaposition is striking.

Acknowledging a need to better control costs, the Army responded to the GAO by clarifying its service requirements, by publishing a handbook of performance standards,[37] and by placing greater emphasis on cost, especially in performance criteria. It re-oriented the criteria to weigh cost more heavily and to require ongoing reductions.

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[35] For background on these issues, see Department of the Army (2003); for a more general discussion of concerns about readiness in this and other contracts, see GAO (2003).

[36] GAO is now known as the “US Government Accountability Office”; at the time of the report cited here, it was known as the “US General Accounting Office.”

[37] The Army issued a call to more closely scrutinize services just prior to the publication of the GAO report.

The Army's response may reflect a natural shift in priorities. At the start of an operation, the Army may seek to allocate managerial talent and manpower to mission-essential activities; it may be more willing—and able—to devote these resources to controlling costs as the operation proceeds.

Lessons for Future Operations

The foregoing analysis applies the US military's risk-management framework to the BSC to consider hazards, both prospectively and retrospectively. The results suggest four general lessons for future operations.

First, not all risks are inherently contractual. Few of the hazards uncovered in the BSC were "contractual" *per se*; most were environmental or activity-based, including those stemming from trade-offs that the Army—or any customer—routinely faces, regardless of the provider. Were the hazards attributed solely to contracting, any subsequent risk controls (including any decisions to replace contract personnel with troops) might be ineffectual or worse. Staffing with troops will not guarantee the "right" services if the customer asks for the "wrong" services; alternatively, a staffing mandate will not correct a statement of work, but may incur unnecessary costs.

But, risks are not identical across providers. The probability and severity of hazards and the costs of controls may differ by type of provider, as in the case of security requirements. Moreover, in some instances, the hazards themselves will differ, as when concerns arise about the chain of command or about the status of contractor employees under international law. Clearly, the results of the analysis will be circumstance-specific and will depending on conditions in the operating environment.

The real lesson is to compare risks, controls, and costs across potential service providers—be they contractors, US military, host nation, or otherwise—considering both common and unique hazards and conditions in the operating environment. For example, a contractor's employees may require more security than US military personnel, especially in an unstable operating environment, such as at or near the battlefield, but the Army may still use fewer resources on balance if opts for the contactor.

Second, risk is dynamic, and appropriate responses may change over time. Prominent concerns at the start of an operation may differ vastly from those at the end of an operation. Action typically dominates the start. Initially, the customer must focus on getting the job done and might be willing to pay a premium to do so, especially if it means increasing mission effectiveness by freeing up managerial talent and manpower for other purposes. The customer, either explicitly or implicitly, may be considering the "price" of controlling cost in the face of other resource constraints. However, as the operation proceeds and conditions stabilize, concerns about cost tend to increase. GAO criticisms of the BSC and the Army's response suggest that cost became a more central theme as conditions stabilized in the Balkans.

Third, the contract is only as good as its customer. The success of a contract hinges first on its design and then on its execution, including the selection process, management, and oversight.[38] This means that the customer must be able to:

- Clearly establish and articulate its needs, including its preferences for cost and quality in the face of tradeoffs;
- Carefully review the contractor's plans, firmly negotiate appropriate cost estimates, and judge the validity of actual costs;
- Uphold its preferences during the performance-evaluation process; and
- Communicate effectively, coordinate activities, and respond to changes in the operating environment as they arise.

Here too, the customer faces a potential hazard; that is, if it is overly prescriptive in stating its needs, it may lose some of the flexibility it initially sought in the contract, especially in a performance-based, IDIQ contract.

A participatory "cast of thousands" may bring a richness of talents, skills, and other resources to the contract, but it also adds complexity and potential conflict to design and execution. By implication, each participant—not just a single monolithic customer—must understand the terms of the contract and, as already noted, its roles and responsibilities under the contract.[39]

For all these reasons, good training, especially with potentially less familiar constructs like CPAF contracting, is essential.

Fourth, risk management is not risk elimination. Not all risk can or should be eliminated, but decisions about how much risk to accept should be made consciously and intentionally with adequate information. The Army—or any other customer—can structure a contract to address many forms of risk, but it may want or need to tolerate some. The costs of controls might be too high in view of the probability and severity of the consequences. Moreover, as conditions in the operating environment change, decisions about risk controls and acceptance may also change.

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[38] For more recent evidence on this point, see GAO (2004).

[39] Wynn (2000) also emphasizes the importance of clarifying roles and responsibilities.

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Contractors Supporting Combat Operations: A Failure of Imagination

Presenter: Richard L. Dunn, University of Maryland, is an independent consultant and Senior Fellow at the University of Maryland. He conducts research in national security operations primarily emphasizing the analysis of laws, policies, and practices that impact the effective implementation of technology. His research includes a variety of acquisition issues, including “contractors on the battlefield.” He has previously made presentations on that subject at the NPS Acquisition Research Symposium and has published a feature comment on the subject in *Government Contractor* magazine.

Dunn retired from Government after serving as the General Counsel of the Defense Advanced Research Projects Agency. Previously, he was with the National Aeronautics and Space Administration, engaged in the private practice of law, and served on active duty as a Judge Advocate in the USAF.

Dunn received a BA (cum laude) from the University of New Hampshire, a JD from the University of Maryland, and a LLM (Highest Honors) from George Washington University.

Abstract

The reasons for the prevalence of contracted support for military deployments and combat operations are well known. In the 1990’s, the military force structure shrank as a dividend of the end of the Cold War. Contemporaneously, outsourcing proved its worth in both the private and public sectors. The Army pioneered a logistic civilian augmentation program (LOGCAP) followed by somewhat similar programs in the Navy and Air Force. While the support of civilians (both government and contractor) to the military was not new, the potential scope of the support and the existence of on-call world-wide support under LOGCAP was. In addition, the sophistication of weapons systems—especially those just entering the inventory—made civilian-specialist support essential. Moreover, the decision to devote more of the shrinking military to the fighting “tooth” rather to than the supporting “tail” tended to reduce KP, latrine details, and similar functions that had once been hallmarks of military service.

Currently, the public debate concerning contractors supporting military operations seems to be dominated by “contracting” concerns rather than “military operations” concerns. Policy is driven not from the point of view of operations, but the point of view of contracting with its myriad rules and cast of players (many far removed from the scene of operations). Fortunately, a “one team/one fight” spirit seems to have prevailed so far in combat zones despite questionable bureaucratic responses and examples of political rhetoric approaching demagogy.

Iraq dominates the current debate for obvious reasons. It is the scene of the most widespread and intense combat operations and the largest contingent of contractors supporting deployed military forces. Iraq is also the prime example of the potential mischief caused by a policy driven by the contract mentality rather than the operations mentality. No one is in charge! No one person, no one commander is in charge of, or even knows how many, contractors are in Iraq. This is not only a management problem but a potential legal (and perhaps not too much of a stretch to say, moral) problem.

While Iraq serves as an example of the frailty of current policy, the real failing is a lack of vision or imagination. The lessons of history and examples from other countries should be considered in crafting the optimum policy for contracted support for military operations. World War II is rich in lessons for various responses to problems we confront today; many of those lessons have been ignored. Foreign countries have crafted policies, such as Britain's sponsored reserves, which while not panaceas, could prove beneficial if intelligently adapted and implemented in the environment of the American military.

Our current system fails on a number of scores. Its failure of imagination is also a failure to implement some obvious and tried principles. The first principle that is ignored is unity of command. This should apply to the contractors who are now so important to the success of military operations as well as to the military. Part of the problem is that our so-called "contracting" system is more a regulatory system than true contracting. A contracting regime should have as its prime principle *facilitating* transactions rather than *regulating* them. Personnel in a combat zone should be subject to certain common standards. A common code governing criminal conduct is prime among these. This research concludes that while policy development has addressed many important issues, it has lacked vision and failed to address or even recognize key top-level issues.

Panel 7 - Complexity and Collaboration in Acquisition Organizations

Wednesday, May 16, 2007 1:45 p.m. – 3:15 p.m.	**Panel 7 - Complexity and Collaboration in Acquisition Organizations**
	Chair: **Dr. Robert Buhrkuhl**, Director, Joint Rapid Acquisition Cell, Office of the Under Secretary of Defense (Acquisition, Technology and Logistics) **Discussant:** **Lt. Col. Lawrence S. Ryder**, USMC, Deputy Program Manager, Joint High Speed Vessel, PEO Ships **Papers:** ***Application of a Network Perspective to DoD Weapon System Acquisition: An Exploratory Study*** **Nancy Roberts** and **Ryan Mantz**, Naval Postgraduate School ***Developing Collaborative Capacity: A Diagnostic Model*** **Susan Page Hocevar, Erik Jansen** and **Gail Fann Thomas**, Naval Postgraduate School

Chair: Dr. Robert Buhrkuhl, Director, Joint Rapid Acquisition Cell, Office of the Under Secretary of Defense (Acquisition, Technology and Logistics), was born in Slater, Missouri and graduated from Central Missouri State University in 1969, with a Bachelor of Science degree in Law Enforcement and Political Science. He earned a Master of Business Administration degree from that same institution in 1971, and was simultaneously designated a Distinguished Military Graduate and commissioned a Second Lieutenant in the United States Army. Dr. Buhrkuhl continued his formal civilian education by earning a Doctor of Philosophy degree in Public Policy Analysis and Administration, St. Louis University, in 1981. His professional military and civilian education also includes: Military Police Officer Basic Course; Civil Affairs Officer Advanced Course; Psychological Operations Course; Defense Resource Management Course; Planning, Programming, and Budgeting Course; Command and General Staff College; Army War College; Program Management Course; Senior Executive Leadership Course; and the Defense Leadership and Management Program, Class of 1997.

Dr. Buhrkuhl is a Level III Certified Acquisition Professional in Program Management and Business Financial Management. He is the author/co-author of five publications, two regarding Zero Based Budgeting, one regarding Transportation, one regarding the implementation of the Program Executive Officer (PEO) concept in Army Aviation, and one regarding Joint Warfighting Experiments. Dr. Buhrkuhl was also directly involved in the "standing-up" of the Comanche Program Management Office (PMO), the Special Operations Aviation PMO, the Combat Support Aviation PEO, and the Comanche Business Office at Texas Instruments.

In his current position, Dr. Buhrkuhl is responsible for leading the JRAC, which consists of a core group of Senior Executive Service and General Officer personnel, in meeting urgent materiel and

logistics requirements which have been certified as being operationally critical by the Combatant Commanders, the military services, and the Defense agencies.

In his prior AT&L position, Dr. Buhrkuhl provided ongoing leadership and acquisition management oversight for 82 Major Defense Acquisition Programs (MDAPs) and pre-MDAPs from the Army, Navy and Air Force whose total acquisition funding exceeds $1,117 trillion. Additionally, he was responsible for all monthly Defense Acquisition Executive Summary briefings to the USD(AT&L); Earned Value Management reporting; submission of Selected Acquisition Reports to Congress; and the review, processing, and coordination of all MDAP Acquisition Strategies, Acquisition Program Baselines, and Acquisition Decision Memorandums that were the result of Defense Acquisition Board deliberations.

Prior to assuming his position at the USD(AT&L), Dr. Buhrkuhl was the Director of Management, Special Operations Acquisition and Logistics Center, United States Special Operations Command, MacDill AFB, where he was responsible for Program Integration (including Life Cycle Cost Estimating and PPBS); Acquisition Policy and Logistics (including Foreign Comparative Testing); Information Technology Management; Management Operations; and the Technical Industrial Liaison Office. His past assignments also include: Acting Deputy/Assistant PEO, Aviation PEO; Program Analysis Officer, Aviation PEO and Combat Support Aviation PEO; Budget Officer, Troop Support Command; and Supervisory Budget Analyst and Program Analyst, Aviation Research and Development Command. Dr. Buhrkuhl has also worked in private industry on two occasions. In 1985, he worked as the Business Manager, Helicopter Systems Branch, Texas Instruments, Inc.; and from October 1989 to March 1991, he worked as a Senior Program Manager, DCS Corporation.

Dr. Buhrkuhl also managed a second career as an officer in the United States Army Reserve. As an Army reservist for over 23 years, he attained the rank of Colonel and served in a number of leadership positions including: Commander; Budget Officer; Team Leader; and Management Analyst. For the last eight years of his Army Reserve career, he was assigned to the Office of the Assistant Secretary of the Army for Research, Development and Acquisition, Pentagon.

Dr. Buhrkuhl's civilian awards include: Exceptional Civilian Service Award; Meritorious Civilian Service Award; Superior Civilian Service Award; six Special Act Awards; and numerous Exceptional Performance Awards and Letters of Commendation. His military awards and decorations include: National Defense Service Ribbon; Meritorious Service Medal; three Army Commendation Medals; three Army Achievement Medals; and the Armed Forces Reserve Medal.

Dr. Buhrkuhl is married to the former Bonnie L. Bruce of Maplewood, Missouri. They have one son, Brad, who lives in Atlanta, Georgia and is an Information Management Technology Specialist.

Application of a Network Perspective to DoD Weapon System Acquisition: An Exploratory Study

Author: Nancy Roberts is a Professor of Defense Analysis in the Graduate School of Operational and Information Sciences at the Naval Postgraduate School in Monterey, California. She received a PhD from Stanford University, a MA and BA from the University of Illinois, and a Diplome Annuel, from the Cours de Civilization Francaise at the Sorbonne. Her previous faculty appointments have been at the Graduate School of Business at the Naval Postgraduate School, the Carlson School of Management at the University of Minnesota, and the Graduate School of Business at Stanford University as a visiting associate professor. Dr. Roberts has published extensively in the areas of public entrepreneurship and innovation, strategic management and planning, leadership, stakeholder collaboration, complex networks, dialogue and deliberation. Her recent work focuses on "wicked problems" such as the organizational challenges of peace operations and post-conflict reconstruction. She is the co-author of *Transforming Public Policy: Dynamics of Public Entrepreneurship and Innovation* (1996) and editor of two books—*The Transformative Power of Dialogue* (2002) and *Direct Citizen Participation* (2007).

Dr. Roberts is also a co-editor of a book series on *Research on Public Management* for Information Age Publishing, an Associate Editor of PAR, and serves on the editorial boards of *Public Management*, *The American Review of Public Administration*, *International Public Management Journal,* and *International Public Management Review*. She currently teaches courses on *Tracking and Disrupting Dark Networks*, *Planning and Organizing in Complex Networks*, and *Coping with Wicked Problems*.

Presenter: Major Ryan Mantz, USAF, has served in various program management and acquisition staff positions for over 14 years. He is currently serving as the Chief of Systems Engineering at the NATO Airborne Warning and Control Programme Management Agency in Brunssum, the Netherlands. As the Lead System Integrator in the Implementation Division, Maj Mantz oversees the technical performance of upgrades to improve the effectiveness of the NATO AWACS fleet and training systems. Major Mantz has also served at both Air Staff- and Center-level positions, including policy/transformation action officer, Program Manager, and Deputy Program Manager. He was Program Manager for the development projects on the Air Force Control Network where his communication upgrades enabled satellite command and control over commercial communication links. He has also served as Deputy PM for the ACAT I, ICBM Propulsion Replacement Program.

Major Mantz' education includes a Master's of Business Administration from the Naval Postgraduate School, a Master's of Science in Environmental Science from the University of Texas at San Antonio, and a Bachelor's of Science in Economics from the United States Air Force Academy.

Abstract

One of the foundations of military command and control is that authority must match responsibility. Yet in weapon system acquisition, a program manager is responsible to deliver capabilities to the warfighter without full control of the resources he needs to carry out this task. Successful program managers recognize their dependencies upon other actors and execute their programs using a network with a common goal of enhancing a specific warfighting capability. A hierarchical chain of command still exists, but the network enables the actors to carry out their objectives in an efficient and effective manner. This report describes how the acquisition process purportedly works in hierarchical terms. It also introduces a process model to describe the set of activities actually used and the actors who

are required to collaborate to deliver capabilities to the warfighter. The analysis of those activities between actors reveals that weapon system acquisition behaves like a network. Describing acquisition in network terms allows those involved in weapon system acquisition oversight, policy, and practice to have new insights and measurement tools to understand how to improve the weapon systems acquisition process.

Introduction

Prelude

Over one-hundred years ago, the Wright Brothers were the first to accomplish a manned, controlled, heavier-than-air-flight, making history at Kitty Hawk, North Carolina, on December 17, 1903. How did two bicycle mechanics from Dayton, Ohio, accomplish this feat against a host of inventors? And, why did the Wright's lose their advantage and not continue to make aviation history? The answer to both questions revolves around their networks. Early on, the Wright's were not only inventors, they were networked innovators. Shulman concluded that their early success was due to their correspondence and sharing of ideas with Samuel Langley and flight historian Octave Chanute, who had built an extensive network within the aviation community (2002). Following their successful flight, however, the Wright's network was limited through secrecy that was driven by a desire to patent the airplane and secure a monopoly, even Chanute's request for information about their maiden flights (Shulman, 2002). The Wrights cut themselves off from their network, preferring to secure the patents rather than build upon their technological feat. The loss of their network also led to stagnation in their innovation efforts. Glenn Curtiss, on the other hand, was anything but secretive. He and the Aerial Experiment Association built his June Bug aircraft and demonstrated flying to the public. Eventually, Curtiss' collaborative network yielded the invention of 500 aviation devices, many of which are still in use today. His factory invented and sold the flying boat to the Navy, along with 6,000 JN-1 Jenny's, making Curtiss Aircraft one of the largest aircraft companies in the world (Shulman, 2002). In essence, the duel between the Wrights and Curtiss proved that the success of complex projects is predicated upon the structure of the project's network of collaborators.

Would Curtiss recognize today's billion-dollar weapon system programs with their high-stakes decision-making process ensuring that entrepreneurs do not waste precious taxpayer resources? Or, has the world not changed that much… Do successful programs still collaborate and network to successfully deliver capabilities to warfighters?

Acquisition Process Problems

Department of Defense (DoD) weapon system acquisition programs are plagued with performance shortfalls, and even more notably, cost and schedule overruns. Addressing this problem has spawned numerous studies and reforms over many years. Most recently, the push to reinvent government in the 1990s resulted in a series of reforms that led acquisition toward a market-based model. Despite these efforts to improve efficiency, success has yet to be realized, with several recent studies noting increasing cost and schedule overruns. Civilian and military officials at the highest levels in the Pentagon have expressed frustration at the lack of balance among the competing interests of cost, schedule, and performance in weapon system acquisition programs. Given many stakeholders with multiple interests in the acquisition process and the inability of high-ranking officials to achieve a balance among competing interests, assigning a program manager responsibility for balancing cost, schedule, and performance appears to be a nearly impossible task.

In addition to problems managing costs, schedule, and performance, warfighters are asking even more from their weapon systems, requiring capabilities that are joint, interoperable, and able to seamlessly share information. Joint staffs are looking to gain an advantage on the battlefield based upon a revolution in military affairs driven by the explosion in information technology. A weapon system program manager must manage not only her own baseline but, in addition, rely on capabilities from other systems that are also in development.

Alternative Acquisition Organizations

Along with many initiatives to solve the fundamental acquisition problem, the strategic assumptions underlying acquisition reforms point to three alternative organizations: hierarchical control, market solutions, or network collaboration. Powell (1990) concluded that hierarchies, markets, and networks are the three basic forms of organization. Congressional and politically appointed civilian control of the weapon system acquisition process, along with the chain of command within the DoD, makes one think of acquisition in hierarchical terms. Alternatively, weapon system acquisition relies heavily on contractors who possess the know-how and resources to produce major weapon systems. A market-based solution to acquisition problems is also rational. Finally, acquisition programs create the need to cross organizational boundaries for decision-making—necessitating the need for a network form of governance.

The policy-makers and practitioners within the weapon system acquisition process do not typically think of the process in network terms. Yet, Powell (1990) concluded that networks are the predominant form of organization with a very few pure markets or hierarchies in existence. This project is devoted to describing the acquisition process in network terms. Therefore, the research question for this paper is: Does the DoD weapon system acquisition process behave as a network?

The focus of this project is to understand how weapon system acquisition programs accomplish their objectives, and whether those interactions fit within the description of a network. This analysis will offer a new perspective on the acquisition process.

Methodology

Chapter II describes the acquisition process and its interactions with both the warfighters who describe weapon system capability needs and the budget staff who balance alternative needs against fiscal constraints. A process model will be introduced to describe the full set of activities and interactions a program must go through from concept to delivery and operation.

With the activities of the acquisition process in mind, Chapter III highlights the characteristics of networks. A definition of networks is established, and aspects of networks are described from a review of literature. Several network analysis techniques are coupled with a description of operating within networks, allowing an analysis of the acquisition process in network terms in Chapter IV.

Finally, Chapter V offers conclusions to the basic research question of whether weapon system acquisition may be described in network terms. Further, several recommendations are offered to improve this analysis and further apply a network model to acquisition.

Weapon System Acquisition Process

The Department of Defense (DoD) weapon system acquisition process must be described before it can be characterized as a hierarchy, network, or market. This Chapter will describe the acquisition process and its interactions with other key processes. To analyze these interactions, a detailed process model will be introduced that describes the activities and actors involved in transforming inputs into outputs in the form of knowledge and, ultimately, weapon systems.

Background

The mission of defense acquisition is to deliver needed capabilities to warfighters. In the hands of warfighters, these capabilities are able to produce constructive effects on the battlefield. The defense acquisition system is, in essence, developing the set of equipment that will be used to fight the next war. The process of collaboration among competing agencies to make these decisions is a very complex task that combines optimization of doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTMLPF) solutions within the Joint Capabilities and Integration Development System (JCIDS). Additionally, these decisions are dynamic, changing over time in response to environmental variables. This results in changing desires and continuing debate over what is the best solution.

Further, delivering materiel capability requires a complex set of actors, and even more stakeholders, who, from markedly different perspectives, seek to optimize the various processes of technology development, integration, test and evaluation, production, fielding, and sustainment of weapon systems. Nevertheless, the governing directive within the DoD, *Directive 5000.1*, gives the Program Manager the purported authority and the clear responsibility to deliver required capabilities to the warfighter (Department of Defense, 2003a). Therefore, the Program Manager must find ways to shape the capability needs from the JCIDS requirements generation system; choose a design architecture, mature technologies, and develop an acquisition strategy within the Defense Acquisition System; and seek resources from the Planning, Programming, Budgeting, and Execution (PPBE) System. Dynamic interaction among these systems is required to deliver a capability to the warfighter. Kadish, et al., described this interaction as the "Big A" acquisition process (2006). This paper will use this cross-cutting definition of the acquisition process.

This chapter will highlight the key processes and interactions required to deliver a capability. The JCIDS, Defense Acquisition System, and PPBE system will be briefly examined. A process model will be introduced to highlight the depth and complexity of the interactions the acquisition process must perform to deliver a capability.

Joint Capabilities Integration and Development System (JCIDS)

The Joint Capabilities Integration and Development System (JCIDS) was born out of the perception that each service parochially examined alternatives within its own core competencies, rather than from the perspective of a joint warfighting environment. *The Goldwater-Nichols Act* of 1986 created a framework where Combatant Commanders (COCOMs) are responsible for joint operations, and service secretaries and commanders are responsible to organize, train, and equip the military to conduct army, naval, and air operations in support of the combatant commanders (*Goldwater-Nichols Act, 1986*). *The Goldwater-Nichols Act* gave the COCOMs a significant voice in the funding process. JCIDS essentially took the next step and institutionalized a process in which requirements are jointly conceived, validated, and approved prior to each service implementing those needs.

The other effect of JCIDS is to define capabilities gaps rather than threat-driven needs. *The Chairman, Joint Chiefs of Staff Instruction* (*CJCSI*) *3170.01 E* defined capabilities as:

> The ability to achieve a desired effect under specified standards and conditions through combinations of means and ways to perform a set of tasks. It is defined by an operational user and expressed in broad operational terms in the format of a joint or initial capabilities document or a joint doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTMLPF) change recommendation (Chairman of the Joint Chiefs of Staff, 2005).

JCIDS Pattern of Relationships

The drivers of the JCIDS process are the representatives of the warfighting community. The Combatant Commands and Joint Staff run key portions of the process. The services' requirements communities become involved as they sponsor an approach that falls inside one of their warfighting core competencies. One difficulty in the JCIDS process is getting the services involved without corrupting the process by making it a forum for the each service to argue for its preferred approach. JCIDS is supposed to avoid this problem through Joint Staff analysis of capability gaps identified by the Combatant Commands.

Several presentations at the PEO/SYSCOM Conference in December 2003 outlined what are essentially opposing views on the service's role during a panel on aligning JCIDS and the Defense Acquisition System. Dr Glenn Lamartin, OSD(AT&L) Director of Defense Systems noted throughout his briefing that the new JCIDS and Acquisition policies had to be followed with collaborative relationships between the OSD, the Functional Capabilities Boards, and the Services to support decision-making (2003). Dr. Nancy Spruill, OSD(AT&L) Director of Acquisition Resources and Analysis, supported a view that the OSD ought to be the decision-maker in the process, holding cross-cutting Defense Acquisition Boards and either cutting or accelerating service programs to meet joint needs (2003). Essentially, Dr Spruill viewed the services as materiel providers who would react to OSD-defined solutions, whereas Dr Lamartin valued the services' inputs to the joint architectures and decisions as a critical interdependency. The right viewpoint is the one that recognizes how information is distributed. If information that is needed for decision-making is distributed within the services and the combatant commands, the services ought to be involved. If the Combatant Commands and Joint Staff have the information they need to derive alternatives that integrate with current warfighting systems and doctrine, then the services might be viewed as implementers of systems.

JCIDS Realities

As structured as the JCIDS process appears, the reality is that requirements change over time. As technological possibilities and threat conditions change, so do needs of the warfighter. Within the acquisition system, "requirements creep" may show up late in the process in the form of expectations or actual changes to written requirements. JCIDS institutionalized this concept with the Capabilities Production Document, offering the opportunity for requirements changes before entering low-rate initial production (Matthews, 2004). Further, the expectations of the warfighter are often not met in a timely manner because expectations evolve over time. Without changing written requirements, the operational community may interpret what was previously stated in a requirements document differently. Therefore, both the perception and the reality is that the desired outputs of the acquisition system are dynamic.

Planning, Programming, Budgeting, and Execution System

The funding for the program comes through the PPBE process. Every other year, the OSD issues budget guidance, and the services begin a biannual cycle of preparing program objective memorandums (POM) to advocate their program's needs among other service priorities. Eventually, the OSD comptroller and the Office of Management and Budget (OMB) prepare the defense portion of the President's Budget. Even though Congress normally appropriates money for only each fiscal year, the POM for a program portrays the budget reflected in the Future Year Defense Program. This, in essence, gives the budget community a forecast of what the budget will look like to satisfy spending priorities for the next several fiscal years.

The Planning, Programming, Budgeting, and Execution system is a centralized, structured way of allocating resources to support the National Security Strategy. McCaffrey and Jones described the goal of PPBE as balancing forces, equipment, and support given resource constraints (2004). Given the competitive nature of the services, this process allows the Secretary of Defense to balance competing objectives and select the most beneficial use of resources.

The overlap of the planning, programming, budgeting, and execution phases, along with the multitude of disparate stakeholders, makes the system very complex. Nonetheless, there is structure from the strategies of the planning phase, to the alternatives of the programming phase, the constraining of the budgeting phase, and finally, the execution phase where funds are appropriated, allocated, re-allocated, and expended. Lewis, Brown, and Roll contend that the Air Force budget process includes centralized planning and decentralized execution with the Major Commands (MAJCOMs) playing a key role as the interface with the COCOMs. The JCIDS process generates capability needs that flow through Air Staff to OSD to become part of the budget. Budget and manpower flow through Air Staff to the program office for execution (2002).

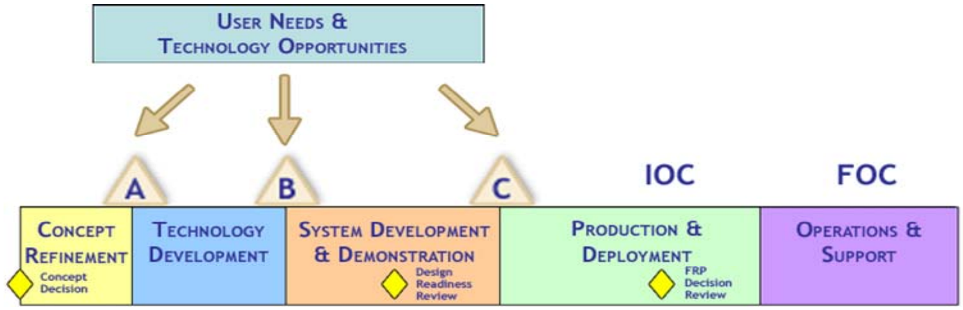
Defense Acquisition System

The Defense Acquisition System refines concepts; matures technologies; develops and integrates system designs; and tests, produces, sustains, and disposes of weapon systems in response to warfighter needs. The Department of Defense Directive (*DODD 5000.1*) (Department of Defense, 2003a, sec. 3.2) governing weapon system acquisition defines an acquisition program as: "a directed, funded effort that provides a new, improved, or continuing materiel, weapon or information system or service capability in response to an approved need."

The sponsor (i.e., a Major Command in the Air Force) uses the JCIDS process as outlined above to define the need. The interface with the acquisition community is through the Initial Capabilities Document. This input is refined in the concept-refinement phase through the Analysis of Alternatives process to select a materiel alternative that is operationally and cost-effective. The sponsor is responsible for the analysis of alternatives using a collaborative process with the acquirer, developer, tester, and other enabling communities to refine the "art of the possible" (Air Force, 2005, p. 9).

The acquisition process uses a high-level framework as shown in Figure 1 that serves as a common reference and set of expectations for all programs. The reality is that every program is unique. An infamous retort within the acquisition community when asked a general question about acquisition programs is, "It depends." The expectations for each program are established through the milestone decision authority at a milestone decision.

Figure 1. Acquisition Phases and Milestones
(Department of Defense, 2003b)



Despite many interdependencies across the acquisition stakeholder community, *DoD Directive 5000.1* names the milestone decision authority and program manager as key participants. The milestone decision authority is given overall responsibility for the program, while the program manager is, "the designated individual with the responsibility for and authority to meet program objectives" (2003a). The reality, however, is that the program manager must collaborate among many interests to accomplish program objectives. Collaboration using integrated product teams (IPT) is the tool designated to resolve competing interests. The collaborative process is not specified in detail, although *DoD Directive 5000.1* (2003a) lists the communities that ought to participate in collaborative decision-making and identifies the IPT as the entry point for organizations that want to collaborate. The program manager and milestone decision authority use the IPTs' advice to make better decisions (Department of Defense, 2003a).

Weapon system acquisition process model

Purpose

Given a plethora of the stakeholders and a complex product-development process, the set of interactions required to manage a program need to be well understood. Describing the process to manage an acquisition program helps assess who interacts and how they interact to accomplish a program. The Assistant Secretary of the Air Force (Acquisition Integration), SAF/AQX, formed the Acquisition Process Action Team (APAT) in Spring 2005 to describe the set of processes Air Force weapon systems were using to accomplish their missions. The goals were to baseline the acquisition processes and form a common language and basis of measurement across the stakeholders in the acquisition process. The group focused mainly on the defense acquisition system itself and its interactions with JCIDS and PPBE.

Lt. Col. Michael Paul and Major Ryan Mantz, SAF/AQXA, led the APAT effort. A group of consultants from the Center for Reengineering and Enabling Technologies (CRET) provided the methodology and manpower to support the data-gathering effort. Mr. Mike Wilhelm, CRET, was instrumental in managing the effort.

In order to assess the interactions within weapon system acquisition, the APAT used an enterprise process-model approach. A process model offers a look across the many disciplines within weapon system acquisition to understand what behaviors the team is using to solve the problem. The model is put into process terms, where each step is defined as a verb-subject relationship. Instead of describing a contracting/source selection process,

the step is simply "Select Source." This allows the team to focus on the stakeholders' inputs to the process instead of driving the description solely in contracting terms.

Another important aspect of a process model is to describe the relationship between the steps and other actors. In essence, the process model is a look at the interdependencies within the acquisition system. Each step in the process is described in terms of inputs, outputs, triggers, and mechanisms. A source of those characteristics is also described. This allows the model to describe interaction with other steps in the process.

Data Gathering

The APAT team used the *DOD 5000* series regulations as a jumping-off point. The major steps in the process were chosen as the high-level steps in the process. This allowed the model to refer back to a reference to which acquisition, logistics, finance, contracting, test, and requirements personnel could relate. Beginning with the high-level process, the APAT team held several workshops with a core group to decompose the high-level process into a series of lower-level process steps. To ensure that the process model reflected the interactions across the Air Force acquisition process, the team established a series of workshops with acquisition personnel to refine the second-level of the model and develop the third and lower-levels of the model. Each workshop lasted approximately two days and was focused on a particular phase of the acquisition process. Participants from all bases were invited, but the main, working-level participants were from the host base. A series of workshops were held at the Pentagon, Eglin AFB, Warner-Robins AFB, and Wright-Patterson AFB, which gathered 120 collective participants from across acquisition functions of requirements, engineering, test, program management, finance, sustainment, maintenance, and disposal. Further, telephone conferences were held to refine the results.

Results

The team used the following definitions as part of the process-decomposition effort:

Process	Logical set of steps transforming an input into an output
Inputs	Information or resource consumed in the activity to create the output
Outputs	Information produced by an activity
Suppliers	Those who provide the input to the process
Customers	Those who receive the output of the process
Key Players	Those ultimately responsible for the process being accomplished
Controls	Business rules that govern the performance of an activity
Mechanisms	Resource that performs or supports an activity, but is not consumed by the activity

Processes were decomposed into roughly five to seven sub-processes that were the key components of the higher-level process. The workshop participants were instructed to keep decomposing processes until they were defined at an "actionable level." In reality, the processes were decomposed until workshop participants could not agree on sub-processes that generally fit most programs.

Appendix A depicts the output from the APAT effort. The APAT effort identified 27 process steps supporting the five major *DoD 5000* acquisition phases. Beneath the major

processes are 107 sub-processes with 172 supporting activities. The workshop participants were more comfortable with the latter three phases of the acquisition process than the first two. Concept Refinement and Technology Development had fewer sub-process and supporting activity steps upon which participants were able to agree.

Even more important than the numbers of steps are the key players, suppliers, and customers of each process step. To make the data more manageable for this paper, key sub- processes and supporting activities were chosen in the Concept-refinement, Technology-development, and System-design and Development phases of the acquisition process. These phases shape the program and lock-in the design characteristics that affect cost schedule and performance during the latter phases. Therefore, this paper focuses on these early phases of acquisition.

What is a Network?

Introduction

Chapter II defines both how weapon system acquisition purportedly and actually behaves. There is a defined, hierarchical chain of command with a milestone decision authority and a program manager who is responsible for delivering a weapon system capability. The APAT process study also revealed that the inputs required to deliver this capability require a set of stakeholder interactions that go outside the boundaries of the traditional chain of command. Further, the stakeholders involved have differing and dynamic objectives causing both real and perceived instability within the acquisition process. First, however, to address the question of whether the defense acquisition system can be characterized as a network, one must first define networks and understand their basic properties.

Markets, Hierarchies, and Networks

The specialized support required for a project often conjures up images of hierarchical organizations that integrate these specialties together for a common purpose. Alternatively, a project might be accomplished through the marketplace where products and services are efficiently offered to those who have the highest willingness to pay. Ronald Coase's early work on transaction costs compared firms and markets as alternatives to one another. According to Coase, firms resorted to hierarchy when it was less costly compared establishing and monitoring individual contracts in a market. The growth of the firm was balanced with the increasing expenses to organize a larger labor force due to diminishing marginal returns. Eventually, the cost of an additional transaction within the firm was equal to the cost of contracting in the marketplace for the same goods or services (Coase, 1937).

Powell introduced the concept that a network existed between a self-forming marketplace and a hierarchical organization. He rejected the view that networks are neither part of a market-to-hierarchy continuum, nor do they represent a hybrid form of hierarchy. As evidence, Powell offered two examples that pointed to the existence of networks. He noted the blurring of the boundaries between markets and inter-organizational collaborations, such as cooperative joint ventures. His second example was the creation of enduring relationships between hierarchies and their consulting, law, and banking firms—indicating that a network form of governance existed between these organizations (1990).

Defining Networks

Why Network?

Before delving into the definitions of a network, it is worth noting the inherent strengths and weaknesses of each form of organization. Markets are ideal for simple transactions in which inputs and outputs are measurable and are not based on a number of contingencies. Coase (1937, p. 287) described the marketplace as: "under no central control […] supply is adjusted to demand, and production to consumption."

Hierarchies evolved to control the specialized inputs needed to produce complex products or services for which the inputs may not be available in the commercial marketplace. Coase (1937) used the classic example of specialized labor where a firm chose to employ an individual with specific skills, thereby internalizing the uncertainties associated with inputs. Additionally, the firm would also observe that person's work on the job and make adjustments (Williamson, 1973). Therefore, hierarchies excel when inputs have uncertainty, since they allow internal observation and adjustment during the course of business.

Networks are adept at handling uncertainty associated with both inputs and outputs. O'Toole (1997) described uncertainty as leading to wicked problems that cannot be divided into tasks that are isolated from each other. Powell agreed that networks form as organizations choose to pool resources to manage uncertainties, thereby creating interdependencies from which a firm cannot easily walk away. He elaborated that networks are particularly adept at exchanging resources that are difficult to measure, such as "know-how, technological capability, a particular approach or style of production" (1990, p. 304).

Network Definition

While a network is fairly well understood in today's society, such familiarity with networks may lead to a variety of definitions. The most straight forward definition of a network comes from sociology. Borgatti and Foster (2003, p. 992) described this type of governance this way: "A network is a set of actors connected by a set of ties." Marsden and Lin (1982) and Knoke and Kuklinski (1991) emphasized persistent relationships among actors, focusing on their relationships rather than the actors themselves or the groups to which they belong. Whereas an actor continues to exist apart from the network, a network does not exist without the relationship between the actors.

Another example of networks comes from the field of public administration where networks are used among government, non-government, and private agencies. Kickert, Klijn, and Koppenjan (1997, p. 6) described networks as "stable patterns of social relations between interdependent actors, which take shape around policy problems and/or policy programmes." This definition is broad, spanning coalitions of intergovernmental and non-governmental actors organized around both issues and delivery of public goods and services.

This report will utilize the Kickert, et al. (1997) definition of networks in which actors are dependent upon one another; there are lasting, stable relationships; and the network is formed around a policy or project. In comparing this definition with others, Klijn (1997) identified three characteristics of networks:

- Networks form due to interdependencies between actors.
- Networks consist of multiple actors who have their own objectives.

- Networks consist of the lasting relationships between the various actors.

The first condition for a network is interdependencies. Klijn (1997) suggested resource dependency is a key driver of lasting relationships since organizations require exchange of capital, personnel, and knowledge with other organizations. Powell (1990) and Jones, Hesterly, and Borgatti (1997) similarly emphasized actors within networks performing complex exchanges and transactions using trust and norms rather than market-driven, legally enforceable contracts.

Again, the condition for more than one actor comes into the definition with the added criteria that each has his/her own objectives. Scharpf (1978) concluded that within government, there is no single actor and no unifying goal. Instead, policy was a result of interactions among multiple actors in which coordination is achieved through exchanges of material, information, and legitimacy.

The final characteristic of networks is that they are composed of lasting relationships among the actors. Klijn (1997) and Jones, Hesterly and Borgatti (1997) concluded that relationship patterns in a network are defined according to their frequency over time. Repeated interactions strengthen the relationship. As a pattern of behavior develops during on-going interactions, actors will begin to understand who they can trust and who they cannot trust. Therefore, the basis for the network is the willingness to establish interdependency based on that frequent, lasting relationship.

Network Analysis

Network Structure

In analyzing a network, the individuals within the network are not as important as the relationships between them. Since networks imply interactions in which no one individual has all the resources to solve a problem, the dyadic relationship is the basic unit of structure. At the next higher level of analysis, the network as a whole will determine the success of outcomes. How the dyadic relationships are arranged to form a network count in achieving a result. Therefore, structure determines how the group as a whole will perform.

Figure 2. Asymmetric Informational Network
(Knoke, 1990, p. 237)

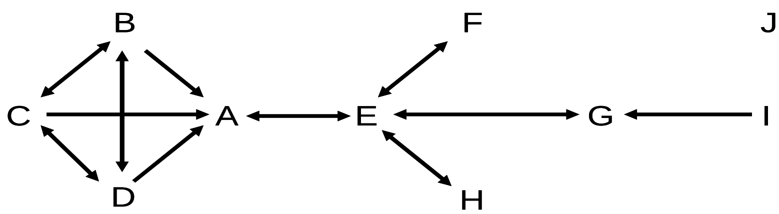


Table 1. Matrix Representation of an Asymmetric Network
(Knoke, 1990, p. 237)

	A	B	C	D	E	F	G	H	I	J	Total
A		0	0	0	1	0	0	0	0	0	1
B	1		1	1	0	0	0	0	0	0	3
C	1	1		1	0	0	0	0	0	0	3
D	1	1	1		0	0	0	0	0	0	3
E	1	0	0	0		1	1	1	0	0	4
F	0	0	0	0	1		0	0	0	0	1
G	0	0	0	0	1	0		0	0	0	1
H	0	0	0	0	1	0	0		0	0	1
I	0	0	0	0	0	0	1	0		0	1
J	0	0	0	0	0	0	0	0	0		0
Total	4	2	2	2	4	1	2	1	0	0	18

To illustrate the concepts of measuring information flow in a network, a hypothetical example of a network in which actors exchange information asymmetrically is shown in Figure 2. The arrows depict the flow of information. An adjacency matrix is used to represent this information flow from actors to one another. The number one in a row represents transmitting information from the actor in the row to the actor in the column, whereas a zero indicates that no information is transmitted. The number one in a column represents receipt of information, and a zero represents no information receipt. Knoke (1990) developed the above matrix in Table 1, concluding from the totals for the columns and rows that A receives the information from more sources, and E transmits information to the most actors.

Actors' Positions within the Network

Switching from the network back to the individual actor as a unit of analysis, the above tools also allow an assessment of how the actor fits into the structure of the network. Freeman (1977) introduced measures of a node's centrality based on his definition of position centrality: "the degree they stand between others, and can therefore facilitate, impede or bias the transmission of messages." These nodes control the information flow in the network more than others.

Centrality appears to be directly correlated with the efficiency of the network and the power of the individual who is more central. Freeman (1977) applied centrality measures to other studies of communication in small group settings, and concluded that centrality was related to solving problems with speed, efficiency and personal satisfaction. Likewise, Krackhardt's (1990) work correlated Freeman's measures of centrality to perceived power in a small, entrepreneurial organization.

Relating Network Structure to Network Effectiveness

From the perspective of the network as a whole, a definition of network effectiveness must be defined on multiple levels across multiple agencies. Provan and Milward (2001)

offer the community, or area the network serves, the network itself, and the organization and participants as the levels among which a network should be evaluated to satisfy multiple stakeholder perspectives. Their empirical study developed the following conclusions:

- Networks are more effective when they are integrated through centralization, although networks that are integrated through a core agency and integrated through dense links among members will be less effective than those are integrated through a core agency alone.
- Networks are most effective when external controls are directly applied, rather than applied through an agency.
- Networks are most effective when a degree of stability is achieved, especially when the stability and uncertainty impacts clients.
- When the above conditions are optimal, resource scarcity will limit the effectiveness of the network. Conversely, resource abundance allows the network to range from low to high effectiveness, depending on the conditions above.

Analysis

Application of the network Perspective to weapon system acquisition

Chapter II described the acquisition system and its formal hierarchical operating structure. Chapter III introduced the network perspective and its basic assumptions and methodology. This chapter draws on the data from the APAT process model and concludes that the acquisition system has network-like properties. The implications of the acquisition system's network characteristics are explored in terms of acquisition governance.

Interdependencies between Actors

One of the key characteristics of a network is the relationships between the actors. Interdependencies between actors are the basis for the formation of networks (Klijn, 1997; Powell, 1990; Jones, Hesterly & Borgatti, 1997). The interdependencies are based on the exchange of resources, and develop in situations in which the actors need capital, personnel, and knowledge to accomplish their objectives (Klijn, 1997).

To deliver a weapon system, numerous actors are involved, as shown in the relationship matrices in Appendix B. One of the key interdependencies during the acquisition process is the exchange of knowledge between actors. During the first three phases of the acquisition process, knowledge about what you need to buy and how the system should be designed to meet that need is the focus of the activities. As shown in Appendix A, Process 1.0, the outputs of the Concept Refinement phase include an approved Course of Action, identification of resources needed for the next phase, approved milestone decision documents, a signed acquisition-decision memorandum, and a technology-development strategy. All of this knowledge is based on the collaborations among the stakeholders during each activity.

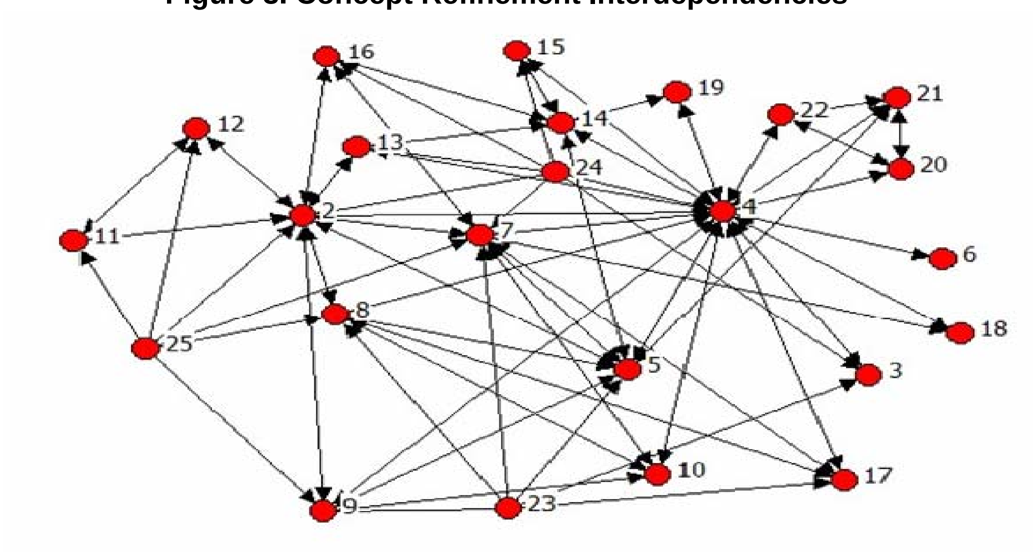
The interdependencies between actors for Concept Refinement are modeled in Figure 3. For modeling purposes, the interactions are assumed to be two-way, directed collaborations. The relationships are those that are specified in the Concept Refinement processes or may be inferred from the type of documents that are approved during that phase. For example, approval of a Test Evaluation Master Plan for a large program

requires an OSD (DOT&E) signature. Of course, these are not the only relationships that a program might need to carry out the objectives of this phase of the acquisition cycle. This is a minimum set that one would expect to see for any major acquisition program.

The diagram shown in Figure 3 illustrates the interdependencies required to define the weapon system concept, select the course of action, and prepare for the Technology Development phase. As one could guess based on the description of responsibilities in JCIDS and the *DoD 5000* series regulations, the lead acquisition organization program manager (node 4), the MAJCOM requirements organization (node 2), and the milestone decision authority (node 5) have critical roles during this phase. Freeman's measure of degree centrality (1977) for those nodes is relatively higher indicating the probability that they will control resources in the network.

Graphically, Figure 3 portrays the collaboration required with the other 22 actors to accomplish the outputs of this acquisition phase. Individually, the lead acquisition organization, the MAJCOM requirements organization, and the milestone decision authority do not interface with all of the other actors. The spreadsheet in Appendix B for the Concept Refinement interactions denotes the lead acquisition organization collaborating with 18 other actors. Of the seven actors with which the lead acquisition organization does not interface, the program manager must rely on other organizations to gather information from those parts of the network.

Figure 3. Concept Refinement Interdependencies

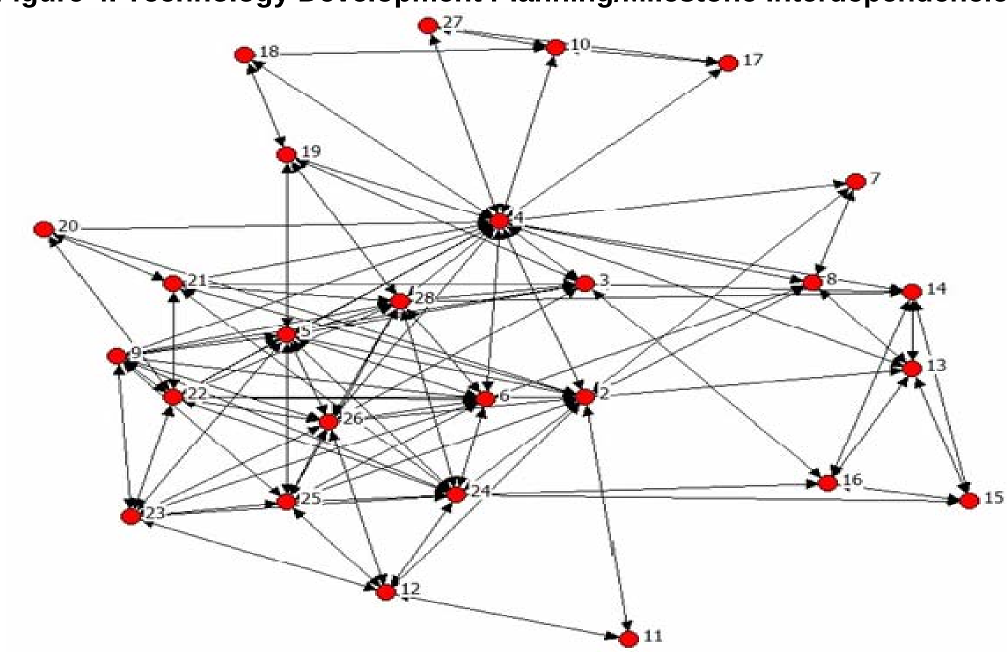


Given a weapon system concept, the purpose of the Technology Development phase of the acquisition process is to mature key technologies and to plan for weapon system development. These two activities require a diverse set of interdependencies. Maturing technology requires an in-depth understanding of the concept and system architecture as well as a diverse network of technology providers. Furthermore, the program must define the capability needs in the Capabilities Development Document (CDD). Along with the capability needs, operational, support, maintenance, and interoperability concepts must be refined so the weapon system may be designed with these plans in mind. The acquisition systems engineering, test, logistics, contracting, and financial-management communities collaborate with the warfighters to translate concepts into an executable acquisition program.

To understand these interactions, this analysis focuses on process 2.1.2, *Identify Technologies for Maturation*, process 2.1.3, *Define Technology Maturation Plan*, and process 2.5, *Develop and Prepare Documents for Milestone B*, which the APAT model decomposed as noted in Appendix A. The diagram of the interdependencies for this phase is illustrated in Figure 4, while the matrix-view is in Appendix B.

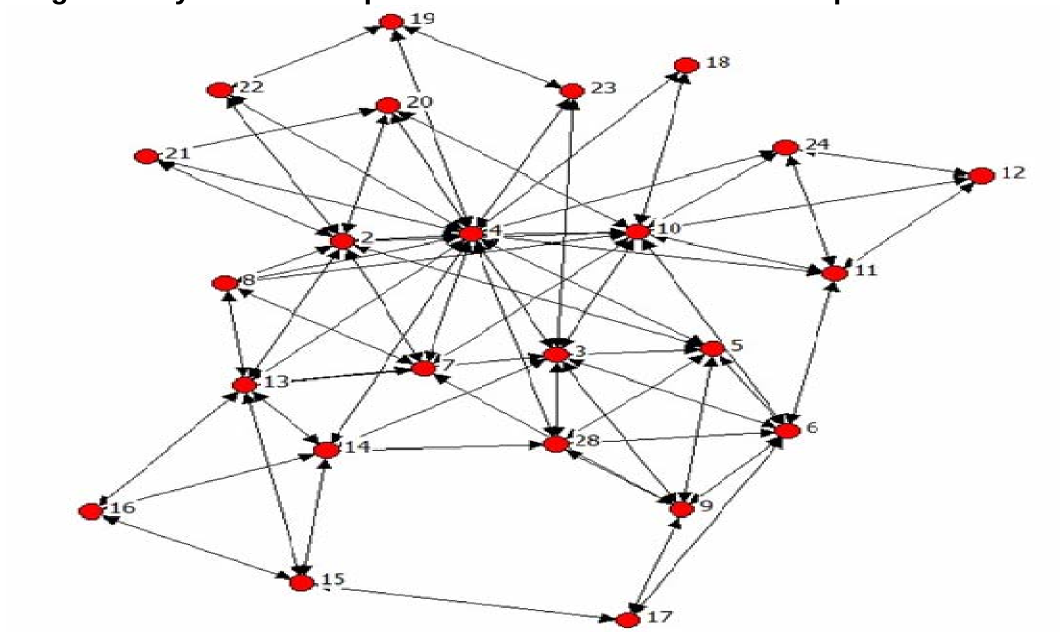
The diagram in Figure 4 reveals that there are 28 actors involved in the acquisition program, an increase from the Concept-refinement phase. Based on degree centrality, the lead acquisition organization/program manager (node 4) remains the most central actor, maintaining many of the relationships from the previous phase. Likewise, the MAJCOM requirements organization (node 2) and the milestone decision authority (node 5) also maintain their central role. A number of other actors at the OSD and service-level become more prominent, as demonstrated by their degree centrality. The network relies on relationships with these actors to provide guidance and priorities that shape the program from an operational, acquisition strategy, and budget perspective. Therefore, the influence of the key actors is still great, but there are many relationships developing during this phase that are beyond the control of the key actors.

Figure 4. Technology Development Planning/Milestone Interdependencies



During System Development and Demonstration, the critical activities include allocating requirements and developing a design, testing the design, and preparing for production and fielding of the system. This analysis focuses on process 3.1, *Manage the Program* and process 3.2.3, *Develop Detailed Design* from the APAT effort in Appendix A.

Figure 5. System Development and Demonstration Interdependencies



The diagram in Figure 5 depicts a less dense, decentralized network. In terms of degree centrality, the program manager (node 4) is still the most central actor, although the MAJCOM requirements organization (node 2) is now less central than the contractor (node 10) in influencing the network. The rise of the contractor's centrality indicates the importance of the contractor's information to the network in a monopolistic environment. This measure of centrality for the sole non-governmental actor is of interest to those who want to influence the outcome of the network at the community, network, and organizational levels of analysis.

Multiple, Independent Actors Formed around a Project

Another characteristic of a network is that there is more than one actor who shares some common attribute that forms the context of their relationship. Using the types of network relationships from Knoke and Kuklinski (1991), the actors involved in concept refinement would share several types of relationships. Since information is a key resource, many relationships are communication relations. Relationships with industry might be described in transactional terms, where dollars are expended so resources can be utilized to help gather information on different acquisition concepts. Finally, authority/power relations exist among the relationships. Process 1.1 in Appendix A describes the controls on the process from the Congressional, OSD, and service level. These controls may be targeted specifically at a program, such as when Congress earmarks an appropriation for a specific program.

One of the key questions is whether the actors remain independent to pursue their own objectives for the project. As noted above, there are authority/power relations exerted on the program. In fact, the lead acquisition organization program manager works for the service acquisition executive, typically through the PEO as an intermediate supervisor. Many of the actors, however, do not work for one another. Congress clearly does not work for the program manager, and the converse is also true. In addition, key collaborators such as the MAJCOM and the lead acquisition organization do not work for one another even though they are in the same service. If the lead acquisition organization and the MAJCOM

requirements organization had a dispute, they would have to resolve it at the Chief of Staff of the Air Force/Secretary of the Air Force level. Issues are not resolved typically at that level. Instead, the actors utilize their relationship with one another to collaborate and work through issues.

Lasting, Stable Relationships between Actors

The final characteristic to be analyzed is the pattern of relationships between actors over time. Again, the literature stresses the importance of this characteristic based on the need to strengthen relationships (Klijn, 1997). In long-term acquisition programs with both complexity and uncertainty, this characteristic is important to allow actors to establish trust with one another. This trust enables actors to make transaction-specific investments that will further the objectives of both the actors and the network.

To examine this variable, the set of actors in the first three acquisition phases were analyzed to determine if the relationship spanned multiple acquisition phases—which could last from a couple of years to over a decade. The analysis is inexact since only select processes from the Technology Development phase and System Development and Demonstration phase were analyzed. Nonetheless, a group of 10 actors form 13 enduring relationships that span the formation and development of an acquisition program. This group of key players and their relationships are displayed in Appendix B.

High-degree centrality among this core group denotes the actors who continually control resources over time. Not surprisingly, the program office has the highest degree centrality within this persistent group of core actors. Interestingly, the MAJCOM budget organization and modernization budget integrator on Air Staff, SAF/AQX, also have high-degree centrality—stemming from their control over the fiscal resources needed to execute the acquisition program.

Network Governance

A network view of acquisition allows an analyst to examine outcomes and management strategies in a new way. Rather than focusing on accountability, the focus shifts to understanding how to enable the network as a whole to create greater value. As Provan and Milward (2001) suggested, the effectiveness of the network ought to be analyzed at the community, network, and participant level. Understanding the outcomes desired from acquisition programs across the Congressional and warfighting community, the acquisition community, and the individual organizations within the network allows a holistic analysis of how the network ought to be structured to accomplish these desires.

A review of the data in Appendix B supports the conclusion that the Lead Acquisition Organization/Program Manager is the most central actor within the acquisition process in terms of degree centrality. Furthermore, this actor has the greatest range of relationships, brokering information from the warfighter, budget community, technology community, and contractor. This places the Program Manager in a very important position in the network.

Not all program managers perform equally. Some may be unable to stabilize their inherently unstable networks. Other managers may have perfectly adequate networks, but the manager is unable to understand how to manage in a network. Whatever the case, understanding the structure of the network should enable program managers to understand the environment within which successful programs are executed.

Further, an understanding of the network allows an analysis of second-order effects due to changes in the network. Provan and Milward (1995) concluded that resource scarcity

would limit the effectiveness of any network. When resources are adequate, however, factors such as centralization, direct external controls, and stability may also affect the outcomes of networks. An understanding of the structure of the acquisition program network would allow an analysis of the effects of changes using modeling. The resultant outcomes could be analyzed at the participant, network, and community level. In other words, a network view of acquisition would allow individual participants to understand how their outcomes and the network's outcomes would be affected by the continuing change in policy, resources, and players in the acquisition system.

Conclusions and Recommendations

Conclusions

Research Question

The focus of this paper was to answer the following research question: does the DoD weapon system acquisition process behave as a network?

The characterization of the "Big A" acquisition system as a complex interaction of the JCIDS subsystem, the PPBE subsystem, and the defense acquisition subsystem identified multiple stakeholders who value different outcomes. Each of these players attempts to utilize some form of hierarchy to break down tasks and assign responsibility to ensure task accomplishment.

However, the APAT process model revealed a more complex, interactive process among the JCIDS, PPBE, and the acquisition subsystems. Appendix B portrays the key players in the first three phases of the acquisition cycle. An analysis of these players reveals that many do not work for one another and may have differing objectives. Furthermore, examination of the key activities within the Concept Refinement, Technology Development, and System Development and Demonstration phases, and the interactions of the key players who were involved in the controls, inputs, activities, and outputs of each subsystem, revealed key interdependencies and long, stable relationships among independent actors. This analysis led to the conclusion that weapon system acquisition can be conceptualized as a network.

Further Refinements

Analysis of the APAT process model data also led to an understanding that centrality is not equally distributed within the network. The lead acquisition organizations/program manager is a central figure who has the greatest number of relationships and is most central to the network measured in terms of degree of centrality. Despite the program manager's lack of a high position within a hierarchical model, network analysis reveals that the program manager has the greatest number of contacts and interactions within the network.

Additionally, there is a core group of actors who have a persistent set of relationships during the early, critical stages of the acquisition process. While the program manager is well-placed within this core group, there are other important actors who deal with budgets and have sustained relationships over time. Understanding the structure of this group and their relationships with the rest of the network will be important in helping the acquisition community develop strategies to govern the network and influence changes for improved network performance and outcomes.

Recommendations

Validate the Model

First, the data gathered in the APAT model were intended to serve as a framework to understand the current acquisition process as it applies to a majority of programs. The scope of the data-gathering process limited the ability to focus on all interactions. Therefore, activities such as milestone decisions were described as an exercise in document writing. Those involved in the APAT effort recognized that the documents generated for a milestone decision were actually the culmination of a set of interactions to gather data and develop a strategy for a particular portion of the acquisition program. For this effort, the official who approved the document and the program office WIPT were assumed to be the only participants. This is, in fact, probably not true. Participants might include other organizations, depending on the subject matter of the program and local procedures.

Therefore, the model serves as a good first step to begin to explore certain interactions within the acquisition system. If a certain set of interactions or a set of actors are of interest, gathering more detailed data would be valuable to further the understanding of the network and to validate the model.

Network Framework to Study Improved Outcomes

The data-gathering effort for the APAT model was not prescriptive. While the sponsors of the effort were interested in recognizing areas for improvement, the model was meant to describe the current process. There are reasons for the patterns of relationships established in the model, but there also may be improved ways of interacting.

Indeed, the network model, once validated, could be utilized as a framework to assess program success. Those who control acquisition policy or who participate in acquisition programs likely would be interested in studying how the networks of these programs of interest differ from the norm. *DoD Directive 5000.1* gives the program manager and milestone decision authority flexibility to decide what the correct set of activities and relationships should be for a particular acquisition program. Studying network models of similar programs might enable decision-makers to tailor their efforts and focus resources on valuable relationships. Alternatively, acquisition strategies could be modeled to discover if information flows efficiently and effectively given several scenarios for organizing a program.

Simulate Changes to the Acquisition System

Of course, there are number of challenges within the acquisition process. Consistently delivering cost, schedule, and performance is rare as Augustine and Fabini (1983), Jones (1996), and McNutt (1998) agreed. Improving consistency of the system has spawned a number of changes—some of which are initially declared successful, only to be later discredited for their "unintended consequences." An example is the initiative to give the contractor Total System Performance Responsibility. This initiative gave the contractor more flexibility and responsibility for the performance of the acquisition program. Unfortunately, the effects of this change were probably not studied using a network analysis. The decision-makers acted upon the ideology that the marketplace solved all their problems.

A number of changes to the acquisition system are being considered today. JCIDS mandates that programs have been have a Net-ready Key Performance Parameter (Chairman of the Joint Chiefs of Staff, 2005). This attempt to build a communication system

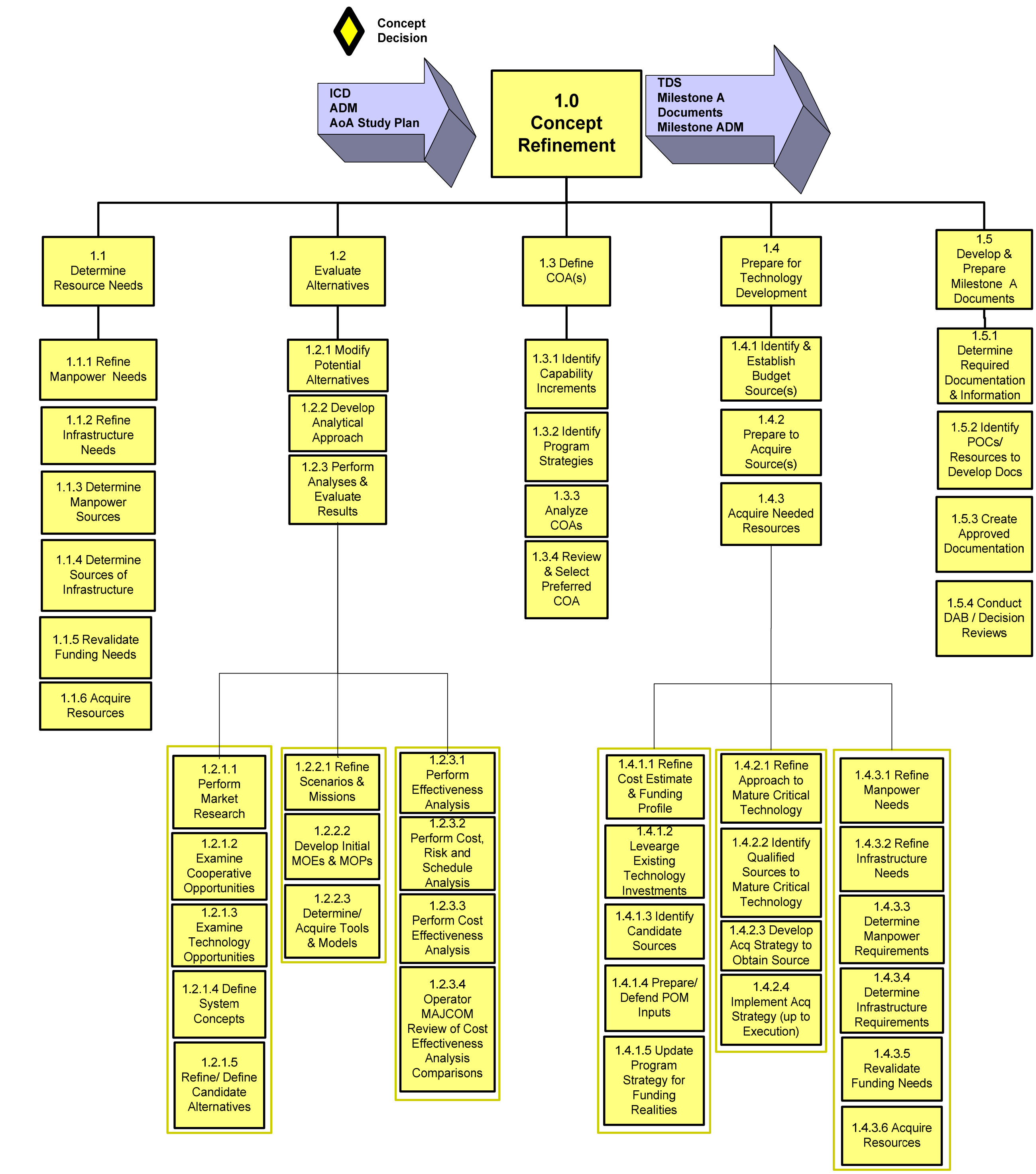
by mandating interoperability from those who will utilize the system is much like the chicken and the egg conundrum. First, the architecture of the network must have some definition. Those who are developing a network and the users of the network must collaborate to solve this problem. Clearly, a network analysis to identify who is involved and how they are collaborating would be more beneficial than mandating a change and hoping that those actors in the network would comply.

Summary

Networks describe both formal and informal ways of getting things done in the acquisition system. The marketplace rarely delivers what the DoD needs at the quantity that it is needed. Some commodities may be purchased in the marketplace, but the uncertainties associated with DoD needs do not allow firms to match their supply to demand. Also, many of the DoD's needs are based on interoperability between programs that must be defined before the market can react to this need. The largest transactions, which involve the lion's share of the modernization budget, rely on the interactions between JCIDS, PPBE, and the acquisition system. A hierarchy exists to account for the resources input into the process. However, the complexities and dynamic nature of the process can best be described as a network of actors who use their relationships to affect outcomes.

Would Glenn Curtiss recognize this network that delivers today's innovative stealth aircraft, advanced combat systems, and ships? He probably would. If you brought Mr. Curtiss into a meeting with a program manager, MAJCOM requirements officer, and a contractor, he would feel right at home. Mr. Curtiss was no stranger to hierarchies given the size of the Curtiss Aircraft Company. Nonetheless, he knew that innovation occurs when a network of collaborators shares ideas to solve their common problems.

Appendix A. DOD 5000 process Model



1.1 Determine Resource Needs for Concept Refinement

Controls	Manpower Models, Laws	Funding & Time Constraints, Leadership Directives	Organizational UMD, STE Caps, OSD Mandates, Statutory Mandates	USAF & Org Priorities,	PPBE Process, Appropriation Laws, New Start Authority,	PPBE Process, Appropriation Laws, New Start Authority, Existing Contracts
Trigger	Trigger: Concept Decision ADM Signed					
Input	ICD *(Operator MAJCOM)* ADM *(MDA)* AoA Study Plan *(Operator MAJCOM)* Lead Acq Organization Identified *(AFMC)*	ICD *(Operator MAJCOM)* ADM *(MDA)* AoA Study Plan *(Operator MAJCOM)* Lead Acq Organization Identified *(AFMC)*	ICD *(Operator MAJCOM)* ADM *(MDA)* AoA Study Plan *(Operator MAJCOM)* Lead Acq Organization Identified *(AFMC)* Identified Manpower Skills & Numbers *(Operator MAJCOM, Lead Acq Org,)*	ICD *(Operator MAJCOM)* ADM *(MDA)* AoA Study Plan *(Operator MAJCOM)* Lead Acq Organization Identified *(AFMC)* Identified Infrastructure Needs *(Operator MAJCOMs, Lead Acq Orgs)*	ICD *(Operator MAJCOM)* ADM *(MDA)* AoA Study Plan *(Operator MAJCOM)* Lead Acq organization Identified *(AFMC)* Specific Manpower identified Specific Infrastructure identified	Funding Requirement *(Operator MAJCOM, Lead Acq Org)* Specific Manpower identified Specific Infrastructure identified
Process	1.1.1 Refine Manpower Needs *(Operator MAJCOM, Lead Acq Org,)*	1.1.2 Refine Infrastructure Needs *(Operator MAJCOM, Lead Acq Org,)*	1.1.3 Determine Manpower Sources *(Operator MAJCOM, Lead Acq Org,)*	1.1.4 Determine Sources of Infrastructure *(Operator MAJCOM, Lead Acq Org,)*	1.1.5 Revalidate Funding Needs *(Operator MAJCOMs, Lead Acq Orgs)*	1.1.6 Acquire Resources *(Operator MAJCOM, Lead Acq Org,)*
Activities	Analyze Management & Subject Matter Expertise Requirements		Make Organic/ Non-Organic Decision	Make Organic/ Non-Organic Decision		May or may not require contract action
Output	Identified Manpower Skills & Numbers *(Operator MAJCOM, Lead Acq Org,)*	Identified Infrastructure Needs *(Operator MAJCOMs, Lead Acq Orgs)*	Specific Manpower identified (both organic or non) *(Operator MAJCOMs, Lead Acq Org)*	Specific Infrastructure identified (both organic or non) *(Operator MAJCOM, Lead Acq Org,)*	Funding Requirement *(Operator MAJCOM, Lead Acq Org)*	Funding Acquired *(Operator MAJCOM, Lead Acq Org)* Specific Manpower Acquired Specific Infrastructure Acquired
Metrics	Not at this point in time	Not at this point in time	Authorized vs. Assigned Manpower	IRR (Infrastructure Readiness Review- CE)	Unfunded Requirement	Authorized vs. Assigned Manpower
Mechanisms	Manpower Models, SM Expertise, Certification Requirements	AFMC - IPT (REUs), SM Expertise	Functional Leads, Prior Experience	Base (CE) Facilities Plan, Facilities Modernization Plan	Cost Models, SME's	Other Available Resources, FFRDC's, Reprogramming Authority

1.2.1 Modify Potential Alternatives

Triggers & Attributes		CONTROL: ITAR			
Input	DOD/ USAF Guidance ICD AoA Study Plan FSA (Functional Solution Analysis) - Data Products	DOD/ USAF Guidance ICD AoA Study Plan FSA (Functional Solution Analysis) - Data Products	DOD/ USAF Guidance ICD AoA Study Plan FSA (Functional Solution Analysis) - Data Products Results of Market Research from 1.2.1.1	Results from 1.2.1.1 & 1.2.1.2 List of System/ Sub-System Impacts to Alts Tech Maturity Assessments DOD/ USAF Guidance ICD AoA Study Plan FSA (Functional Solution Analysis) - Data Products	Set of System Attributes & Performance System Interdependencies & Interoperabilities Definitions of Critical Enabling Technologies ICD Existing Architectures
Process	1.2.1.1 Perform Market Research *(Operator MAJCOM, Lead Acq Org)*	1.2.1.2 Examine Cooperative Opportunities	1.2.1.3 Examine Technology Opportunities	1.2.1.4 Define System Concepts	1.2.1.5 Refine/ Define Candidate Alternatives
Activities		Research Within Service, Joint, Allies Capabilities	Consult DOD Lab Efforts		Refine SV's in Architectures Alternative Impact(s) of the concept to the Existing Architecture Impacts or limitations of the pre-existing architecture
Output	ICD Feedback Potentially Feasible Technology Industrial Capacity Innovative Concepts Commercial Products Available for Adaptation	Opportunities for Within Service, Joint & Ally (Cost Sharing) Alternatives Leverage Common Systems for Multiple Capabilities	List of System/ Sub-System Impacts to Alts Tech Maturity Assessments	Set of System Attributes & Performance System Interdependencies & Interoperabilities Definitions of Critical Enabling Technologies	Candidate Alternatives

1.2.2 Develop Analytical Approach

Trigger	Trigger: AoA Assigned		
Input	System Threat Assessment AoA Study Plan ICD SPG Scenarios & Other Capability Studies Candidate Alternatives (input from 1.2.1)	Approved Scenarios & Details for Modeling System Threat Assessment AoA Study Plan ICD SPG Scenarios & Other Capability Studies Candidate Alternatives (input from 1.2.1)	MOEs & MOPs System Threat Assessment AoA Study Plan ICD SPG Scenarios & Other Capability Studies Candidate Alternatives (input from 1.2.1) Scenarios & Details for Modeling
Process	1.2.2.1 Refine Scenarios & Missions	1.2.2.2 Develop Initial MOEs & MOPs	1.2.2.3 Determine/ Acquire Tools & Models
Activities	Develop Data Sets Review w/ Intel Community	Coordinate/ Collaborate Reviews of MOEs & MOPs	Identify Needed Engineering, Costs, & Operational Models Determine Availability of existing Models Modify/ Refine Models
Output	Approved Scenarios & Details for Modeling	Initial MOEs & MOPs (Threshold & Objective Levels)	Conceptual Engineering, Costs, & Operational Models

1.2.3 Perform Analyses & Evaluate Results

Input	Candidate Alternatives (input from 1.2.1) AoA Study Plan ICD Approved Scenarios & Details for Modeling Initial MOEs & MOPs (Threshold & Objective Levels) Conceptual Engineering, Costs, & Operational Models	Performance Assessment against MOEs & MOPs AoA Study Plan ICD Candidate Alternatives (input from 1.2.1) Approved Scenarios & Details for Modeling Initial MOEs & MOPs (Threshold & Objective Levels) Conceptual Engineering, Costs, & Operational Models	Risk Assessment Cost and Schedule Assessment Performance Assessment against MOEs & MOPs Performance & Capability Drivers(Sensitivities)	ICD Relative Comparison of Alternatives
Process	1.2.3.1 Perform Effectiveness Analysis	1.2.3.2 Perform Cost, Risk and Schedule Analysis	1.2.3.3 Perform Cost Effectiveness Analysis	1.2.3.4 Operator MAJCOM Review of Cost Effectiveness Analysis Comparisons
Activities	Assess Technical Performance / Capability Identify Sensitivities	Perform Risk Analysis Perform Cost & Schedule Analysis	Analyze Results of Cost Effectiveness Analysis	
Output	Performance Assessment against MOEs & MOPs Performance & Capability Drivers(Sensitivities)	Risk Assessment Cost and Schedule Assessment	Relative Comparison of Alternatives	Preferred Alternative

Notes

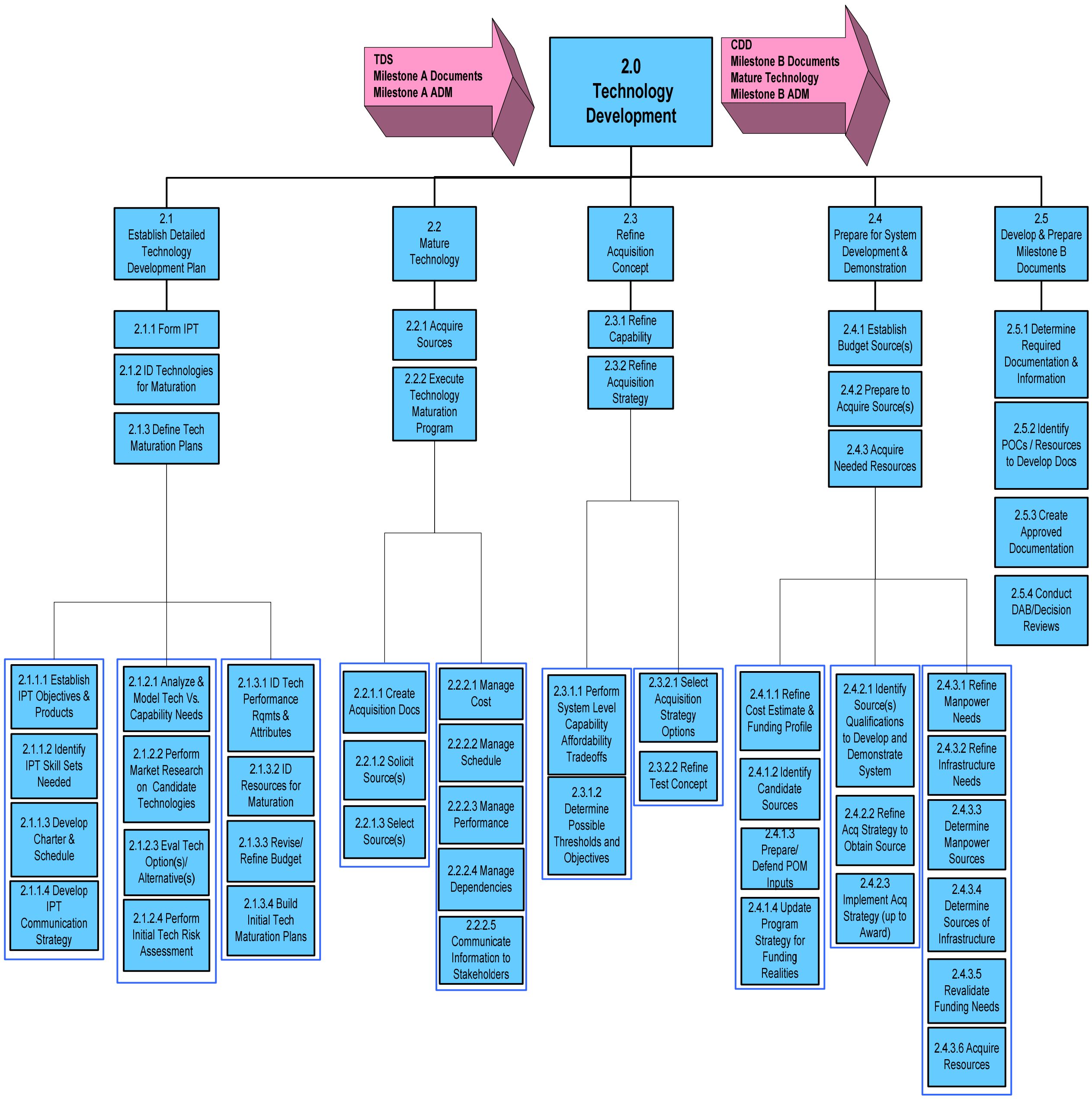
1. Assess Technology Sub System is a part of the Risk Analysis in 1.2.3.2

1.3 Define Alternative Courses of Action COA(s)

Input	ICD Feedback on AoA Out brief Preferred Alternative (input from 1.2.3.4)	ICD Feedback on AoA Out brief Preferred Alternative (input from 1.2.3.4) Potential Capability Increments	ICD Feedback on AoA Out brief Preferred Alternative (input from 1.2.3.4) Potential Program Strategies for COAs	Preferred Alternative (input from 1.2.3.4) ICD Relative Comparison of COAs
Process	1.3.1 Identify Capability Increments	1.3.2 Identify Program Strategies	1.3.3 Analyze COAs	1.3.4 Review & Select Preferred COA
Activity	Brainstorm Potential Incremental Approaches Conduct User Interaction Consider Operator MAJCOM Budget & TOA	Evaluate Historical COA Conduct Systems Engineering Analysis Develop Cost, Schedule, Risk and Effectiveness Estimates Conduct Operator MAJCOM Interaction - review Consider Operator MAJCOM Budget & TOA	Conduct Operator MAJCOM Interaction - Review Consider Operator MAJCOM Budget & TOA	Conduct Lead Acq Review MDA Approves COA Operator MAJCOM Reviews & Approves COA
Output	Potential Capability Increments	Potential Program Strategies for COAs	Relative Comparison of COAs	Approved COA Indication of Next Phase(s)

1.4 Prepare for Technology Development

Trigger	COA Selected		
Input	MAJCOM Budget ICD Approved COA *(Operator MAJCOM)* (input from 1.3.4)	TDS (input from 1.5.1) ICD Approved COA *(Operator MAJCOM)* (input from 1.3.4) Budget Sources Identified	Acq Strategy to Obtain Source(s) TDS (input from 1.5.1) Funding Profile (input from 1.4.1) Approved COA *(Operator MAJCOM)* (input from 1.3.4) ICD
Process	1.4.1 Identify & Establish Budget Source(s)	1.4.2 Prepare to Acquire Source(s)	1.4.3 Acquire Needed Resources (manpower, facilities, etc.)
Output	Updated Program Strategy	Source(s) Selected Agreement in place with Source(s) pending MSA	Specific Infrastructure acquired (both organic or non) *(Operator MAJCOM, Lead Acq Org.)* Funding Requirement *(Operator MAJCOM, Lead Acq Org)*


TDS
Milestone A Documents
Milestone A ADM
2.0 Technology Development
CDD
Milestone B Documents
Mature Technology
Milestone B ADM
2.1 Establish Detailed Technology Development Plan
2.2 Mature Technology
2.3 Refine Acquisition Concept
2.4 Prepare for System Development & Demonstration
2.5 Develop & Prepare Milestone B Documents
2.1.1 Form IPT
2.1.2 ID Technologies for Maturation
2.1.3 Define Tech Maturation Plans
2.2.1 Acquire Sources
2.2.2 Execute Technology Maturation Program
2.3.1 Refine Capability
2.3.2 Refine Acquisition Strategy
2.4.1 Establish Budget Source(s)
2.4.2 Prepare to Acquire Source(s)
2.4.3 Acquire Needed Resources
2.5.1 Determine Required Documentation & Information
2.5.2 Identify POCs / Resources to Develop Docs
2.5.3 Create Approved Documentation
2.5.4 Conduct DAB/Decision Reviews
2.1.1.1 Establish IPT Objectives & Products
2.1.1.2 Identify IPT Skill Sets Needed
2.1.1.3 Develop Charter & Schedule
2.1.1.4 Develop IPT Communication Strategy
2.1.2.1 Analyze & Model Tech Vs. Capability Needs
2.1.2.2 Perform Market Research on Candidate Technologies
2.1.2.3 Eval Tech Option(s)/ Alternative(s)
2.1.2.4 Perform Initial Tech Risk Assessment
2.1.3.1 ID Tech Performance Rqmts & Attributes
2.1.3.2 ID Resources for Maturation
2.1.3.3 Revise/ Refine Budget
2.1.3.4 Build Initial Tech Maturation Plans
2.2.1.1 Create Acquisition Docs
2.2.1.2 Solicit Source(s)
2.2.1.3 Select Source(s)
2.2.2.1 Manage Cost
2.2.2.2 Manage Schedule
2.2.2.3 Manage Performance
2.2.2.4 Manage Dependencies
2.2.2.5 Communicate Information to Stakeholders
2.3.1.1 Perform System Level Capability Affordability Tradeoffs
2.3.1.2 Determine Possible Thresholds and Objectives
2.3.2.1 Select Acquisition Strategy Options
2.3.2.2 Refine Test Concept
2.4.1.1 Refine Cost Estimate & Funding Profile
2.4.1.2 Identify Candidate Sources
2.4.1.3 Prepare/ Defend POM Inputs
2.4.1.4 Update Program Strategy for Funding Realities
2.4.2.1 Identify Source(s) Qualifications to Develop and Demonstrate System
2.4.2.2 Refine Acq Strategy to Obtain Source
2.4.2.3 Implement Acq Strategy (up to Award)
2.4.3.1 Refine Manpower Needs
2.4.3.2 Refine Infrastructure Needs
2.4.3.3 Determine Manpower Sources
2.4.3.4 Determine Sources of Infrastructure
2.4.3.5 Revalidate Funding Needs
2.4.3.6 Acquire Resources

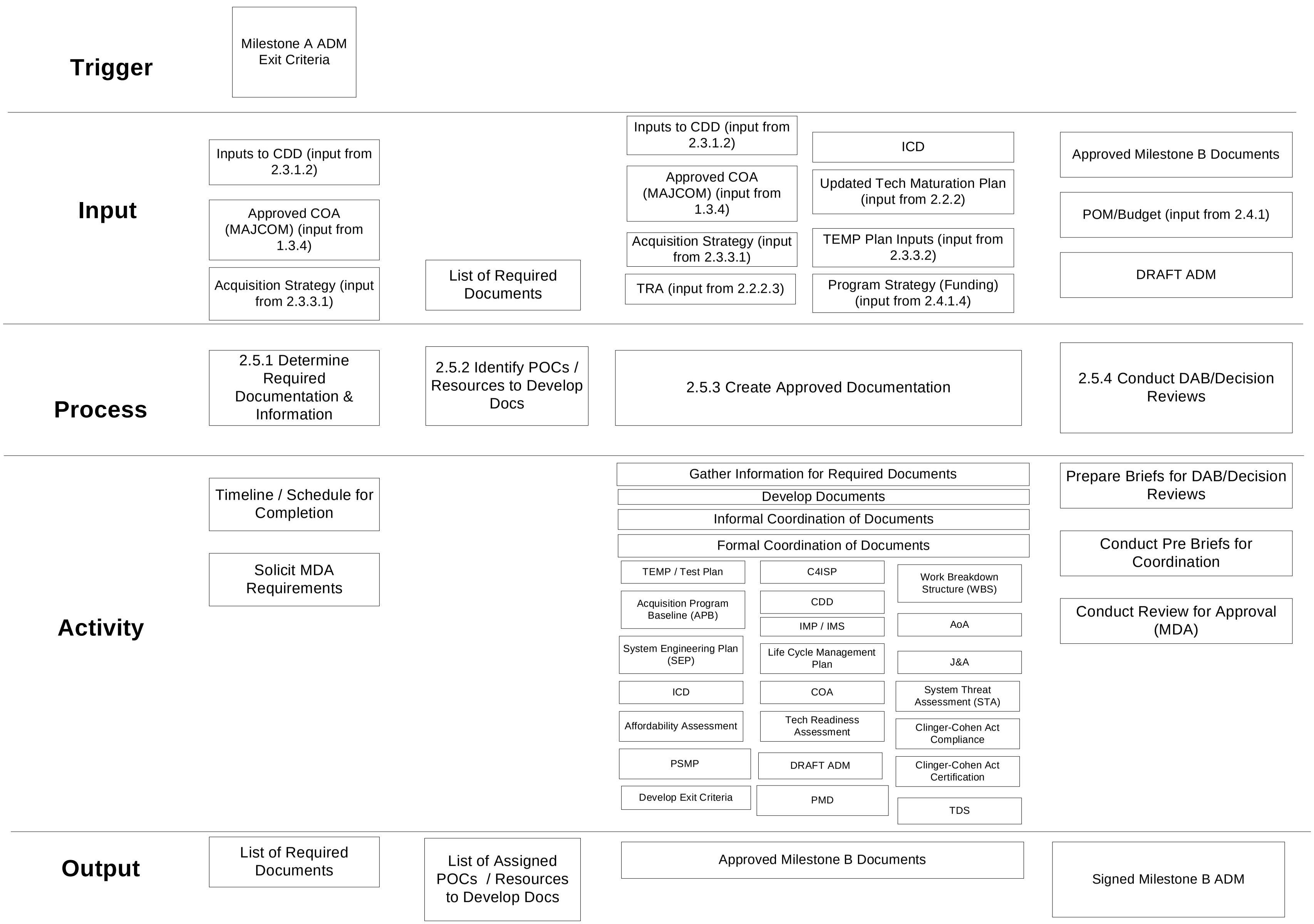
2.1.2 Identify Technologies for Maturation

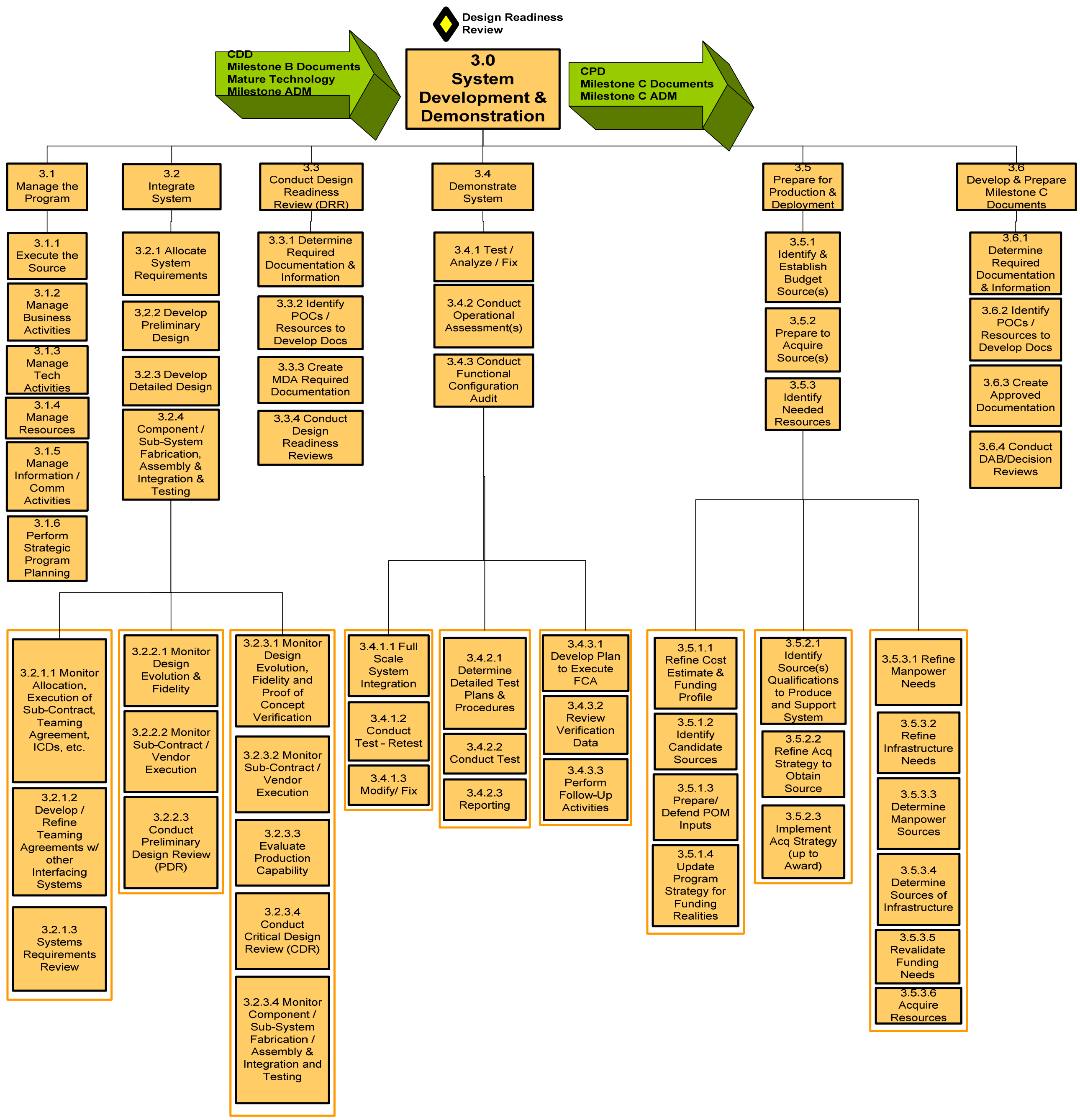
	2.1.2.1	2.1.2.2	2.1.2.3	2.1.2.4
Trigger	Milestone A ADM			
Input	Approved CoA (input from 1.3.4) *(Acq Lead)* TDS (input from 1.5.1) *(Acq Lead)* ICD *(MAJCOM)*	Library of Historical TRAs *(OSD AT&L)* Approved CoA (input from 1.3.4) TDS (input from 1.5.1) *(Acq Lead)* ICD *(MAJCOM)* Candidate Technology (Abilities & Shortfalls) *(Sponsor Agency, IPT)*	Political Influence Approved CoA (input from 1.3.4) *(Acq Lead)* TDS (input from 1.5.1) *(Acq Lead)* ICD *(MAJCOM)* Initial Set of Candidate Technologies *(Sponsor Agency, IPT)*	Selected Tech Option(s)/ Alternative(s) *(IPT, Industry, Labs, etc.)*
Process	2.1.2.1 Analyze & Model Tech Vs. Capability Needs *(IPT from 2.1.1)*	2.1.2.2 Perform Market Research on Candidate Technologies *(IPT)*	2.1.2.3 Eval Tech Option(s)/ Alternative(s) *(IPT)*	2.1.2.4 Perform Initial Tech Risk Assessment *(IPT)*
Activities	Id Thresholds & Objectives Address Tech Integration Challenges & Dependencies	Eval Industrial-base (includes foreign) Eval Gov't Market Share Eval Maturity & Viability	Selection of Technology Balanced Technology Against Other Issues (Systems Engineering, etc.)	Id & Prioritize Tech Risk Down select Tech Options & Alternative(s) Id Risk Mitigation Activities Dependencies
Output	Candidate Technology Abilities & Shortfalls *(Sponsor Agency, IPT)*	Initial Set of Candidate Technologies *(Sponsor Agency, IPT)* Market Research Report *(Sponsor Agency, IPT)*	Selected Tech Option(s)/ Alternative(s) *(IPT, Industry, Labs, etc.)* Tech Readiness Assessment *(Acq Lead, MDA, IPT)*	Initial Technical Risk Mgmt Plan *(Acq Lead)*
Mechanisms	Mechs - None Identified		TRL(s)	
Metrics	Metrics - None Identified			

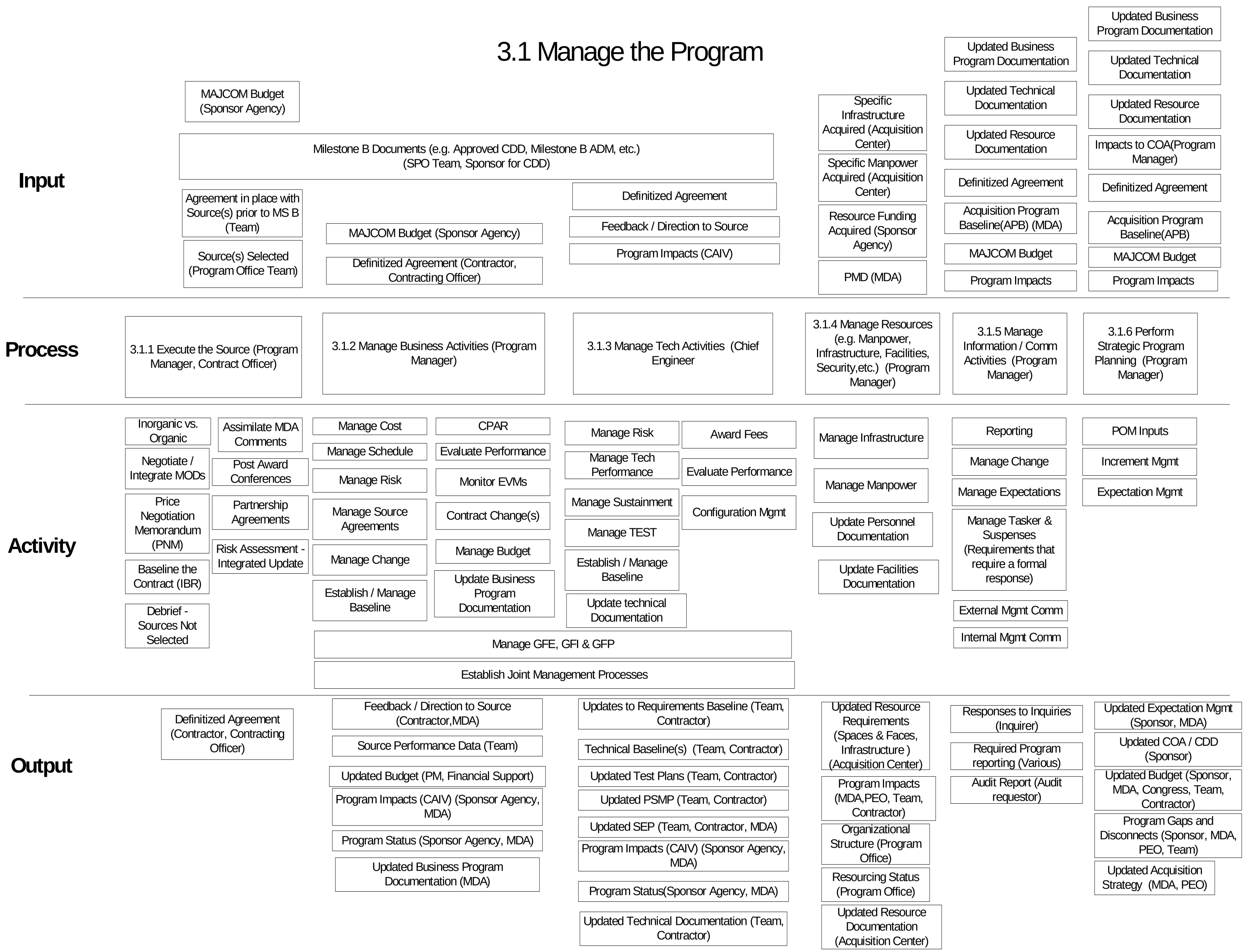
2.1.3 Define Technology Maturation Plan

	2.1.3.1	2.1.3.2	2.1.3.3	2.1.3.4
Trigger	Milestone A ADM			
Input	ICD *(MAJCOM)* TDS (input from 1.5.1) *(Acq Lead)* Selected Tech Option(s)/Alternative(s) (input from 2.1.2.3) *(IPT, Industry, Labs, etc.)* Initial Technical Risk Mgmt Plan (input from 2.1.2.4) *(Acq Lead)*	Market Research Report (input from 2.1.2.2) ICD *(MAJCOM)* TDS (input from 1.5.1) *(Acq Lead)* Selected Tech Option(s)/ Alternative(s) (input from 2.1.2.3) Initial Technical Risk Mgmt Plan (input from 2.1.2.4)	Budget *(Sponsor Agency)* Personnel & Infrastructure for Maturation (	Personnel & Infrastructure for Maturation Performance Rqmts & Attributes Budget Resolution (POM or no $$) Exit Criteria
Process	2.1.3.1 ID Tech Performance Rqmts & Attributes *(IPT)*	2.1.3.2 ID Resources for Maturation *(Acq Lead, IPT)*	2.1.3.3 Revise/ Refine Budget *(IPT)*	2.1.3.4 Build Initial Tech Maturation Plans (includes Transition Plans) *(IPT)*
Activities	Define Detailed Objectives, Thresholds, & Metrics	Personnel ID Infrastructure ID Make Organic/ Contractor Decisions	Revise/ Refine Cost Estimate(s) Compare & Resolve Cost Estimate vs. Budget	Id Tech Sources Allocate Acquisition Responsibilities per Technology (Lead Exec Agency) Conduct Industry Day(s) & Other Outreach Activities
Output	Performance Rqmts & Attributes	Personnel & Infrastructure for Maturation *(Acq Lead)*	Budget Resolution (POM or no $$) *(Acq Lead, Sponsor Agency)*	Initial Tech Maturation Plan *(Sponsor Agency, Acq Lead)*
Mechanisms	TRL Level			

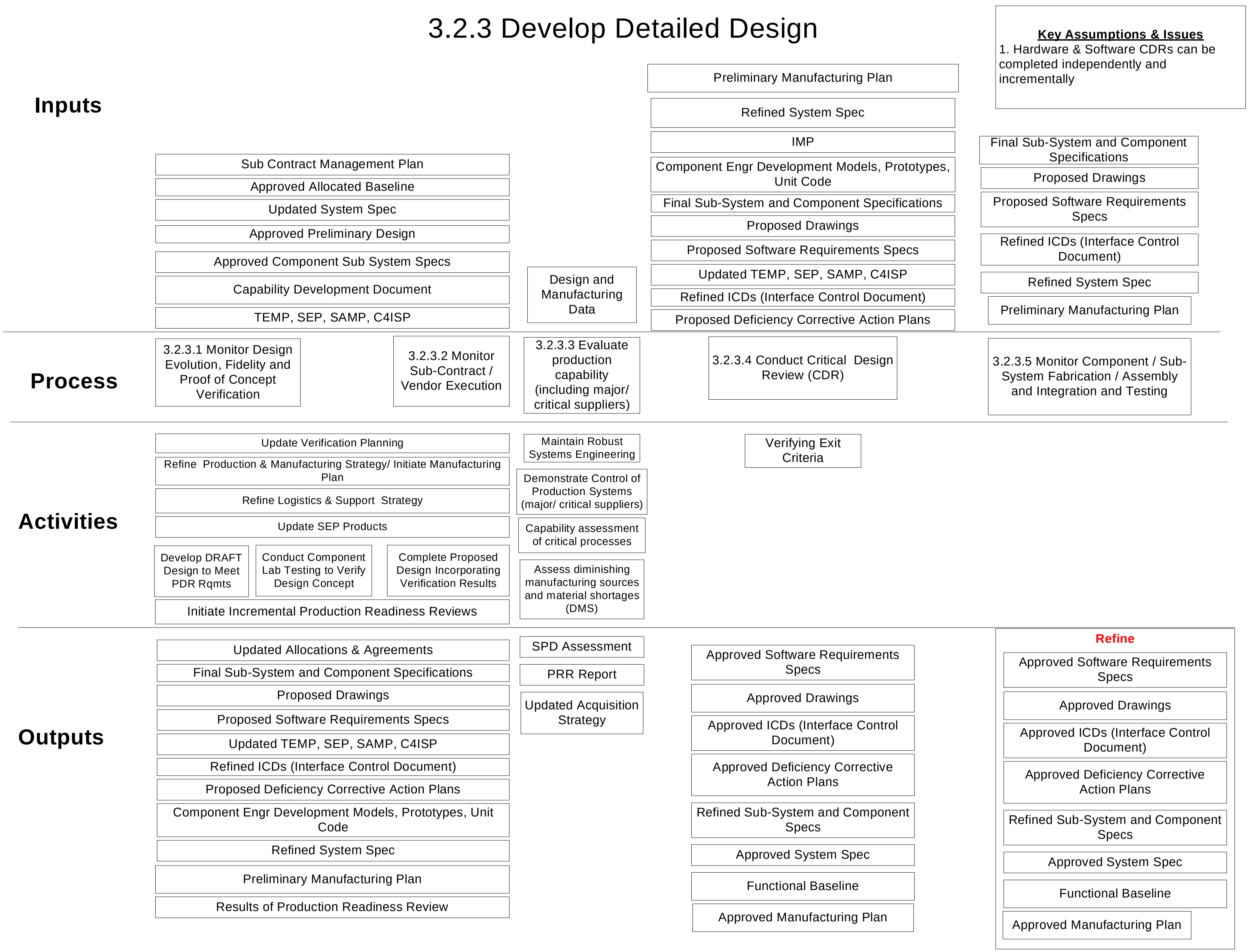
2.5 Develop and Prepare Milestone B Documents

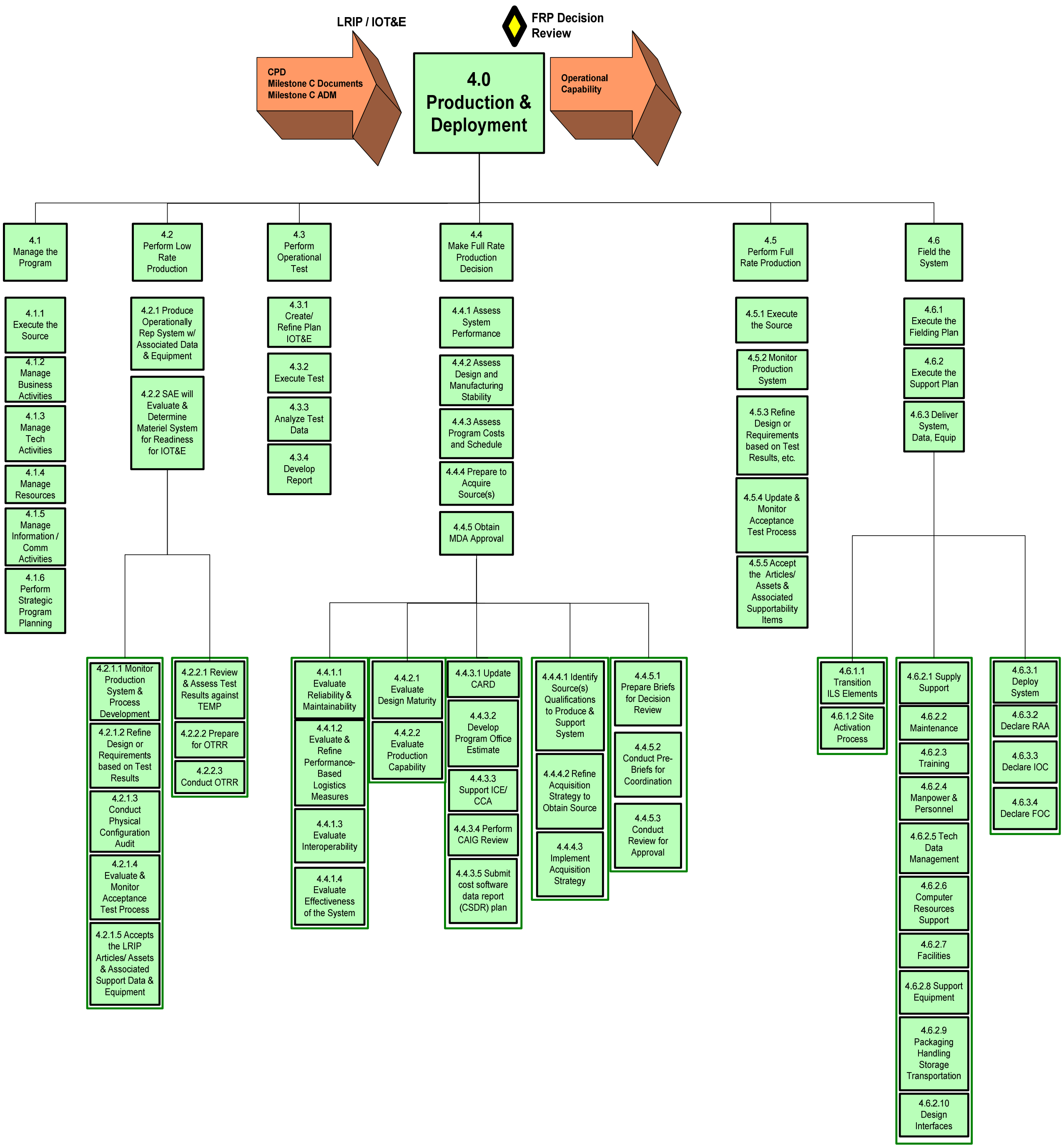


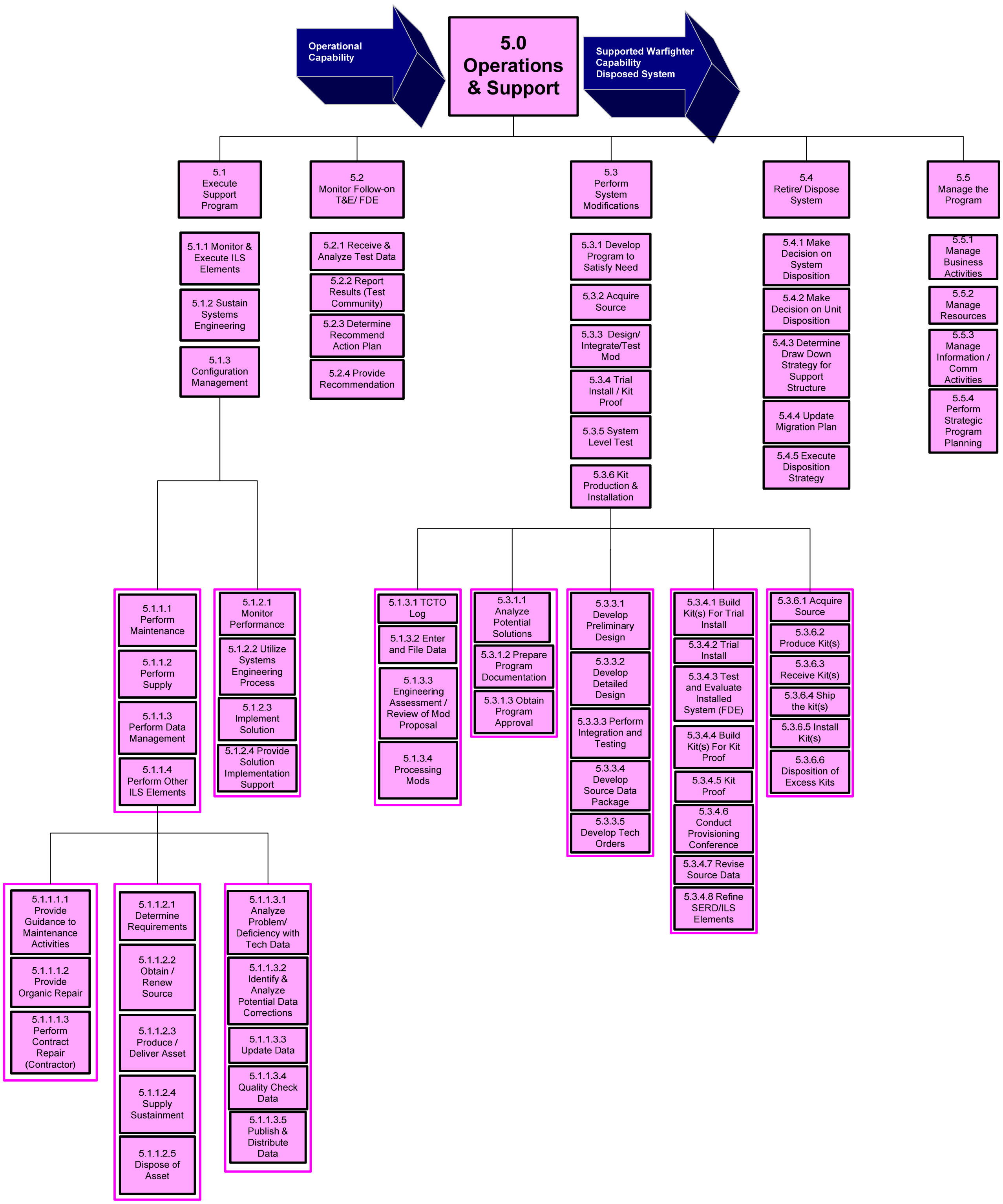

Design Readiness Review
CDD
Milestone B Documents
Mature Technology
Milestone ADM
3.0 System Development & Demonstration
CPD
Milestone C Documents
Milestone C ADM
3.1 Manage the Program
3.2 Integrate System
3.3 Conduct Design Readiness Review (DRR)
3.4 Demonstrate System
3.5 Prepare for Production & Deployment
3.6 Develop & Prepare Milestone C Documents
3.1.1 Execute the Source
3.1.2 Manage Business Activities
3.1.3 Manage Tech Activities
3.1.4 Manage Resources
3.1.5 Manage Information / Comm Activities
3.1.6 Perform Strategic Program Planning
3.2.1 Allocate System Requirements
3.2.2 Develop Preliminary Design
3.2.3 Develop Detailed Design
3.2.4 Component / Sub-System Fabrication, Assembly & Integration & Testing
3.3.1 Determine Required Documentation & Information
3.3.2 Identify POCs / Resources to Develop Docs
3.3.3 Create MDA Required Documentation
3.3.4 Conduct Design Readiness Reviews
3.4.1 Test / Analyze / Fix
3.4.2 Conduct Operational Assessment(s)
3.4.3 Conduct Functional Configuration Audit
3.5.1 Identify & Establish Budget Source(s)
3.5.2 Prepare to Acquire Source(s)
3.5.3 Identify Needed Resources
3.6.1 Determine Required Documentation & Information
3.6.2 Identify POCs / Resources to Develop Docs
3.6.3 Create Approved Documentation
3.6.4 Conduct DAB/Decision Reviews
3.2.1.1 Monitor Allocation, Execution of Sub-Contract, Teaming Agreement, ICDs, etc.
3.2.1.2 Develop / Refine Teaming Agreements w/ other Interfacing Systems
3.2.1.3 Systems Requirements Review
3.2.2.1 Monitor Design Evolution & Fidelity
3.2.2.2 Monitor Sub-Contract / Vendor Execution
3.2.2.3 Conduct Preliminary Design Review (PDR)
3.2.3.1 Monitor Design Evolution, Fidelity and Proof of Concept Verification
3.2.3.2 Monitor Sub-Contract / Vendor Execution
3.2.3.3 Evaluate Production Capability
3.2.3.4 Conduct Critical Design Review (CDR)
3.2.3.4 Monitor Component / Sub-System Fabrication / Assembly & Integration and Testing
3.4.1.1 Full Scale System Integration
3.4.1.2 Conduct Test - Retest
3.4.1.3 Modify/ Fix
3.4.2.1 Determine Detailed Test Plans & Procedures
3.4.2.2 Conduct Test
3.4.2.3 Reporting
3.4.3.1 Develop Plan to Execute FCA
3.4.3.2 Review Verification Data
3.4.3.3 Perform Follow-Up Activities
3.5.1.1 Refine Cost Estimate & Funding Profile
3.5.1.2 Identify Candidate Sources
3.5.1.3 Prepare/ Defend POM Inputs
3.5.1.4 Update Program Strategy for Funding Realities
3.5.2.1 Identify Source(s) Qualifications to Produce and Support System
3.5.2.2 Refine Acq Strategy to Obtain Source
3.5.2.3 Implement Acq Strategy (up to Award)
3.5.3.1 Refine Manpower Needs
3.5.3.2 Refine Infrastructure Needs
3.5.3.3 Determine Manpower Sources
3.5.3.4 Determine Sources of Infrastructure
3.5.3.5 Revalidate Funding Needs
3.5.3.6 Acquire Resources


3.1 Manage the Program
Input
MAJCOM Budget (Sponsor Agency)
Milestone B Documents (e.g. Approved CDD, Milestone B ADM, etc.) (SPO Team, Sponsor for CDD)
Agreement in place with Source(s) prior to MS B (Team)
Source(s) Selected (Program Office Team)
MAJCOM Budget (Sponsor Agency)
Definitized Agreement (Contractor, Contracting Officer)
Definitized Agreement
Feedback / Direction to Source
Program Impacts (CAIV)
Specific Infrastructure Acquired (Acquisition Center)
Specific Manpower Acquired (Acquisition Center)
Resource Funding Acquired (Sponsor Agency)
PMD (MDA)
Updated Business Program Documentation
Updated Technical Documentation
Updated Resource Documentation
Definitized Agreement
Acquisition Program Baseline(APB) (MDA)
MAJCOM Budget
Program Impacts
Updated Business Program Documentation
Updated Technical Documentation
Updated Resource Documentation
Impacts to COA(Program Manager)
Definitized Agreement
Acquisition Program Baseline(APB)
MAJCOM Budget
Program Impacts
Process
3.1.1 Execute the Source (Program Manager, Contract Officer)
3.1.2 Manage Business Activities (Program Manager)
3.1.3 Manage Tech Activities (Chief Engineer
3.1.4 Manage Resources (e.g. Manpower, Infrastructure, Facilities, Security,etc.) (Program Manager)
3.1.5 Manage Information / Comm Activities (Program Manager)
3.1.6 Perform Strategic Program Planning (Program Manager)
Activity
Inorganic vs. Organic
Negotiate / Integrate MODs
Price Negotiation Memorandum (PNM)
Baseline the Contract (IBR)
Debrief - Sources Not Selected
Assimilate MDA Comments
Post Award Conferences
Partnership Agreements
Risk Assessment - Integrated Update
Manage Cost
Manage Schedule
Manage Risk
Manage Source Agreements
Manage Change
Establish / Manage Baseline
CPAR
Evaluate Performance
Monitor EVMs
Contract Change(s)
Manage Budget
Update Business Program Documentation
Manage Risk
Manage Tech Performance
Manage Sustainment
Manage TEST
Establish / Manage Baseline
Update technical Documentation
Award Fees
Evaluate Performance
Configuration Mgmt
Manage GFE, GFI & GFP
Establish Joint Management Processes
Manage Infrastructure
Manage Manpower
Update Personnel Documentation
Update Facilities Documentation
Reporting
Manage Change
Manage Expectations
Manage Tasker & Suspenses (Requirements that require a formal response)
External Mgmt Comm
Internal Mgmt Comm
POM Inputs
Increment Mgmt
Expectation Mgmt
Output
Definitized Agreement (Contractor, Contracting Officer)
Feedback / Direction to Source (Contractor,MDA)
Source Performance Data (Team)
Updated Budget (PM, Financial Support)
Program Impacts (CAIV) (Sponsor Agency, MDA)
Program Status (Sponsor Agency, MDA)
Updated Business Program Documentation (MDA)
Updates to Requirements Baseline (Team, Contractor)
Technical Baseline(s) (Team, Contractor)
Updated Test Plans (Team, Contractor)
Updated PSMP (Team, Contractor)
Updated SEP (Team, Contractor, MDA)
Program Impacts (CAIV) (Sponsor Agency, MDA)
Program Status(Sponsor Agency, MDA)
Updated Technical Documentation (Team, Contractor)
Updated Resource Requirements (Spaces & Faces, Infrastructure) (Acquisition Center)
Program Impacts (MDA,PEO, Team, Contractor)
Organizational Structure (Program Office)
Resourcing Status (Program Office)
Updated Resource Documentation (Acquisition Center)
Responses to Inquiries (Inquirer)
Required Program reporting (Various)
Audit Report (Audit requestor)
Updated Expectation Mgmt (Sponsor, MDA)
Updated COA / CDD (Sponsor)
Updated Budget (Sponsor, MDA, Congress, Team, Contractor)
Program Gaps and Disconnects (Sponsor, MDA, PEO, Team)
Updated Acquisition Strategy (MDA, PEO)

3.2.3 Develop Detailed Design




LRIP / IOT&E
CPD
Milestone C Documents
Milestone C ADM
FRP Decision Review
4.0 Production & Deployment
Operational Capability
4.1 Manage the Program
4.1.1 Execute the Source
4.1.2 Manage Business Activities
4.1.3 Manage Tech Activities
4.1.4 Manage Resources
4.1.5 Manage Information / Comm Activities
4.1.6 Perform Strategic Program Planning
4.2 Perform Low Rate Production
4.2.1 Produce Operationally Rep System w/ Associated Data & Equipment
4.2.2 SAE will Evaluate & Determine Materiel System for Readiness for IOT&E
4.2.1.1 Monitor Production System & Process Development
4.2.1.2 Refine Design or Requirements based on Test Results
4.2.1.3 Conduct Physical Configuration Audit
4.2.1.4 Evaluate & Monitor Acceptance Test Process
4.2.1.5 Accepts the LRIP Articles/ Assets & Associated Support Data & Equipment
4.2.2.1 Review & Assess Test Results against TEMP
4.2.2.2 Prepare for OTRR
4.2.2.3 Conduct OTRR
4.3 Perform Operational Test
4.3.1 Create/ Refine Plan IOT&E
4.3.2 Execute Test
4.3.3 Analyze Test Data
4.3.4 Develop Report
4.4 Make Full Rate Production Decision
4.4.1 Assess System Performance
4.4.2 Assess Design and Manufacturing Stability
4.4.3 Assess Program Costs and Schedule
4.4.4 Prepare to Acquire Source(s)
4.4.5 Obtain MDA Approval
4.4.1.1 Evaluate Reliability & Maintainability
4.4.1.2 Evaluate & Refine Performance-Based Logistics Measures
4.4.1.3 Evaluate Interoperability
4.4.1.4 Evaluate Effectiveness of the System
4.4.2.1 Evaluate Design Maturity
4.4.2.2 Evaluate Production Capability
4.4.3.1 Update CARD
4.4.3.2 Develop Program Office Estimate
4.4.3.3 Support ICE/ CCA
4.4.3.4 Perform CAIG Review
4.4.3.5 Submit cost software data report (CSDR) plan
4.4.4.1 Identify Source(s) Qualifications to Produce & Support System
4.4.4.2 Refine Acquisition Strategy to Obtain Source
4.4.4.3 Implement Acquisition Strategy
4.4.5.1 Prepare Briefs for Decision Review
4.4.5.2 Conduct Pre-Briefs for Coordination
4.4.5.3 Conduct Review for Approval
4.5 Perform Full Rate Production
4.5.1 Execute the Source
4.5.2 Monitor Production System
4.5.3 Refine Design or Requirements based on Test Results, etc.
4.5.4 Update & Monitor Acceptance Test Process
4.5.5 Accept the Articles/ Assets & Associated Supportability Items
4.6 Field the System
4.6.1 Execute the Fielding Plan
4.6.2 Execute the Support Plan
4.6.3 Deliver System, Data, Equip
4.6.1.1 Transition ILS Elements
4.6.1.2 Site Activation Process
4.6.2.1 Supply Support
4.6.2.2 Maintenance
4.6.2.3 Training
4.6.2.4 Manpower & Personnel
4.6.2.5 Tech Data Management
4.6.2.6 Computer Resources Support
4.6.2.7 Facilities
4.6.2.8 Support Equipment
4.6.2.9 Packaging Handling Storage Transportation
4.6.2.10 Design Interfaces
4.6.3.1 Deploy System
4.6.3.2 Declare RAA
4.6.3.3 Declare IOC
4.6.3.4 Declare FOC


Operational Capability
5.0 Operations & Support
Supported Warfighter Capability Disposed System
5.1 Execute Support Program
5.1.1 Monitor & Execute ILS Elements
5.1.2 Sustain Systems Engineering
5.1.3 Configuration Management
5.2 Monitor Follow-on T&E/ FDE
5.2.1 Receive & Analyze Test Data
5.2.2 Report Results (Test Community)
5.2.3 Determine Recommend Action Plan
5.2.4 Provide Recommendation
5.3 Perform System Modifications
5.3.1 Develop Program to Satisfy Need
5.3.2 Acquire Source
5.3.3 Design/ Integrate/Test Mod
5.3.4 Trial Install / Kit Proof
5.3.5 System Level Test
5.3.6 Kit Production & Installation
5.4 Retire/ Dispose System
5.4.1 Make Decision on System Disposition
5.4.2 Make Decision on Unit Disposition
5.4.3 Determine Draw Down Strategy for Support Structure
5.4.4 Update Migration Plan
5.4.5 Execute Disposition Strategy
5.5 Manage the Program
5.5.1 Manage Business Activities
5.5.2 Manage Resources
5.5.3 Manage Information / Comm Activities
5.5.4 Perform Strategic Program Planning
5.1.1.1 Perform Maintenance
5.1.1.2 Perform Supply
5.1.1.3 Perform Data Management
5.1.1.4 Perform Other ILS Elements
5.1.2.1 Monitor Performance
5.1.2.2 Utilize Systems Engineering Process
5.1.2.3 Implement Solution
5.1.2.4 Provide Solution Implementation Support
5.1.3.1 TCTO Log
5.1.3.2 Enter and File Data
5.1.3.3 Engineering Assessment / Review of Mod Proposal
5.1.3.4 Processing Mods
5.3.1.1 Analyze Potential Solutions
5.3.1.2 Prepare Program Documentation
5.3.1.3 Obtain Program Approval
5.3.3.1 Develop Preliminary Design
5.3.3.2 Develop Detailed Design
5.3.3.3 Perform Integration and Testing
5.3.3.4 Develop Source Data Package
5.3.3.5 Develop Tech Orders
5.3.4.1 Build Kit(s) For Trial Install
5.3.4.2 Trial Install
5.3.4.3 Test and Evaluate Installed System (FDE)
5.3.4.4 Build Kit(s) For Kit Proof
5.3.4.5 Kit Proof
5.3.4.6 Conduct Provisioning Conference
5.3.4.7 Revise Source Data
5.3.4.8 Refine SERD/ILS Elements
5.3.6.1 Acquire Source
5.3.6.2 Produce Kit(s)
5.3.6.3 Receive Kit(s)
5.3.6.4 Ship the kit(s)
5.3.6.5 Install Kit(s)
5.3.6.6 Disposition of Excess Kits
5.1.1.1.1 Provide Guidance to Maintenance Activities
5.1.1.1.2 Provide Organic Repair
5.1.1.1.3 Perform Contract Repair (Contractor)
5.1.1.2.1 Determine Requirements
5.1.1.2.2 Obtain / Renew Source
5.1.1.2.3 Produce / Deliver Asset
5.1.1.2.4 Supply Sustainment
5.1.1.2.5 Dispose of Asset
5.1.1.3.1 Analyze Problem/ Deficiency with Tech Data
5.1.1.3.2 Identify & Analyze Potential Data Corrections
5.1.1.3.3 Update Data
5.1.1.3.4 Quality Check Data
5.1.1.3.5 Publish & Distribute Data

Appendix B. Acquisition Networks

A. Concept Refinement Network

	(2) MAJCOM Requirements	(3) AFMC	(4) Lead Acquisition Organization	(5) Milestone Decision Authority (MDA)	(6) Federally Funded Research and Development Centers (FFRDC)	(7) Other Service Programs	(8) Joint Programs	(9) Allied Programs	(10) Industry	(11) Defense Intelligence Agency (DIA)	(12) Combatant Commanders (COCOM)	(13) MAJCOM Budget	(14) SAF/AQ	(15) SAF/FM	(16) AF/XP	(17) Air Force Research Lab (AFRL)	(18) Center Contracting (PK)	(19) Acquisition Center of Excellence (ACE)	(20) AFMC/DO	(21) AF/TE	(22) DOT&E	(23) OSD	(24) AF	(25) Joint Staff	
(2) MAJCOM Requirements	0	0	1	1	0	1	1	1	0	1	1	1	0	0	1	0	0	0	0	0	0	0	1	1	11
(3) AFMC	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	3
(4) Lead Acquisition Organization	1	1	0	1	1	1	1	1	1	0	0	1	1	1	0	1	1	1	1	1	1	0	1	0	18
(5) Milestone Decision Authority (MDA)	1	0	1	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	8
(6) Federally Funded Research and Development Centers (FFRDC)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
(7) Other Service Programs	1	0	1	1	0	0	0	0	1	0	0	0	0	0	1	1	1	0	0	0	0	1	1	1	10
(8) Joint Programs	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	7
(9) Allied Programs	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	6
(10) Industry	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
(11) Defense Intelligence Agency (DIA)	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	3
(12) Combatant Commanders (COCOM)	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3
(13) MAJCOM Budget	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	4
(14) Service Acq Exec (SAF/AQ)	0	0	1	1	0	0	0	0	0	0	0	1	0	1	1	0	0	1	0	0	0	0	0	0	6
(15) SAF/FM	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	3
(16) AF/XP	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	4
(17) Air Force Research Lab (AFRL)	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4
(18) Center Contracting (PK)	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
(19) Acquisition Center of Excellence (ACE)	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2
(20) AFMC/DO	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	3
(21) AF/TE	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	4
(22) DOT&E	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	3
(23) OSD	0	1	0	1	0	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	8
(24) AF	1	1	1	0	0	1	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	1	0	1	9
(25) Joint Staff	1	0	0	0	0	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0	8

B. Technology Development Planning/Milestone Network

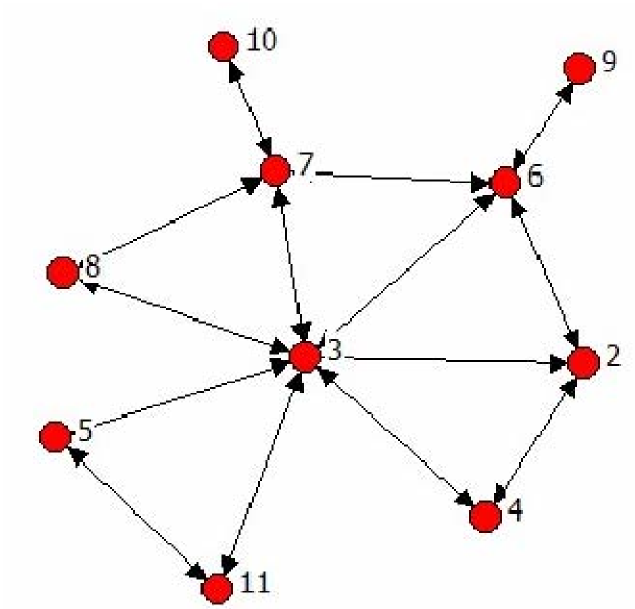
	(2) MAJCOM Requirements	(3) PEO	(4) Lead Acquisition Organization	(5) Milestone Decision Auth (MDA)	(6) OSD/NII	(7) AFMC/LG	(8) MAJCOM LG	(9) OSD (AT&L)	(10) Industry	(11) Defense Intelligence Agency (DIA)	(12) Combatant CCs	(13) MAJCOM Budget	(14) SAF/AQX	(15) SAF/FM	(16) AF/XP	(17) Air Force Research Lab (AFRL)	(18) Center Contracting (PK)	(19) Acq Center of Excellenc	(20) AFMC/DO	(21) AF/TE	(22) DOT&E	(23) OSD	(24) SECAF/ CSAF	(25) Joint Staff	(26) DAB Participants	(27) DARPA	(28) AF Acq Exec	
(2) MAJCOM Requirements	0	0	1	1	0	1	1	0	0	1	1	1	0	0	0	0	0	0	1	1	1	0	1	1	1	0	0	13
(3) PEO	0	0	1	1	0	0	0	1	0	0	0	0	1	0	1	0	0	1	0	1	0	0	0	0	1	0	1	9
(4) Lead Acquisition Organization	1	1	0	1	1	1	1	1	1	0	0	1	1	0	0	1	1	1	1	1	1	0	0	0	1	1	1	19
(5) Milestone Decision Authority	1	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	1	0	1	12
(6) OSD/NII	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	10
(7) AFMC/LG	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
(8) MAJCOM LG	1	0	1	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
(9) OSD (AT&L)	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	10
(10) Industry	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	4
(11) Defense Intelligence Agency	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
(12) Combatant Commanders	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	6
(13) MAJCOM Budget	1	0	1	0	0	0	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	6
(14) SAF/AQX	0	1	1	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	6
(15) SAF/FM	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	4
(16) AF/XP	0	1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	5
(17) Air Force Research Lab (AFRL)	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3
(18) Center Contracting (PK)	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3
(19) Acquisition Center of Excellence	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	5
(20) AFMC/DO	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	4
(21) AF/TE	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	1	7
(22) DOT&E	1	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	1	0	1	11
(23) OSD	0	0	0	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0	8
(24) AF	1	0	0	1	1	0	0	1	0	0	1	0	0	1	1	0	0	0	0	1	1	1	0	1	0	0	1	12
(25) Joint Staff	1	0	0	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	1	9
(26) DAB Participants	1	1	1	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	11
(27) DARPA	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3
(28) AF Acq Exec	0	1	1	1	1	0	0	1	0	0	0	0	1	0	0	0	0	1	0	1	1	0	1	1	1	0	0	12

C. System Development and Demonstration Management/Design Network

	(2) MAJCOM Requirements	(3) PEO	(4) Program Office	(5) Milestone Decision Authority (MDA)	(6) Congress	(7) AFMC/LG	(8) MAJCOM LG	(9) OSD (AT&L)	(10) Contractor	(11) Sub Contractor	(12) Vendor	(13) MAJCOM Budget	(14) SAF/AQX	(15) SAF/FM	(16) AF/XP	(17) OSD(C)	(18) Center Contracting (PK)	(19) Center FM	(20) Test Ranges	(21) AFOTEC	(22) Center CE	(23) Center HR	(24) DCMA	(28) AF Acq Exec	
(2) MAJCOM Requirements	0	0	1	1	0	1	1	0	1	0	0	1	0	0	0	0	0	0	1	1	1	0	0	0	9
(3) PEO	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	1	0	1	9
(4) Program Office	1	1	0	1	0	1	1	0	1	1	0	1	1	0	0	0	1	1	1	1	1	1	1	1	17
(5) Milestone Decision Authority	1	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6
(6) Congress	0	1	0	1	0	0	0	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	7
(7) AFMC/LG	1	0	1	0	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6
(8) MAJCOM LG	1	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	5
(9) OSD (AT&L)	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	6
(10) Contractor	1	1	1	0	1	1	1	0	0	1	1	0	0	0	0	0	1	0	1	0	0	0	1	0	11
(11) Sub Contractor	0	0	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	5
(12) Vendor	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3
(13) MAJCOM Budget	1	1	1	0	0	1	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	8
(14) SAF/AQX	0	1	1	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	1	6
(15) SAF/FM	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	4
(16) AF/XP	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	3
(17) OSD(C)	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3
(18) Center Contracting (PK)	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
(19) Center FM	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	3
(20) Test Ranges	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	4
(21) AFOTEC	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3
(22) Center CE	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3
(23) Center HR	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3
(24) DCMA	0	0	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4
(28) AF Acq Exec	0	1	1	1	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	6

D. Persistent Relationships from Concept Refinement Through System Development and Demonstration

	(2) MAJCOM Requirements	(3) Program Office	(4) Milestone Decision Authority	(5) Contractor	(6) MAJCOM Budget	(7) SAF/AQX	(8) Service Acq Exec (SAF/AQ	(9) SAF/FM	(10) AF/XP	(11) Center Contracting
(2) MAJCOM Requirements	0	1	1	0	1	0	0	0	0	0
(3) Program Office	1	0	1	1	1	1	1	0	0	1
(4) Milestone Decision Authority (MDA)	1	1	0	0	0	0	0	0	0	0
(5) Contractor	0	1	0	0	0	0	0	0	0	1
(6) MAJCOM Budget	1	1	0	0	0	1	0	1	0	0
(7) SAF/AQX	0	1	0	0	1	0	1	0	1	0
(8) Service Acq Exec (SAF/AQ)	0	1	0	0	0	1	0	0	0	0
(9) SAF/FM	0	0	0	0	1	0	0	0	0	0
(10) AF/XP	0	0	0	0	0	1	0	0	0	0
(11) Center Contracting	0	1	0	1	0	0	0	0	0	0



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Developing Collaborative Capacity: A Diagnostic Model

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Abstract

Federal Acquisition Reform acknowledges the importance of effective collaboration among participating organizations. However, both research and practical experience have shown that inter-organizational collaboration can be difficult to achieve. This research builds

on a model developed by the authors with homeland security organizations that identified enablers and barriers to collaborative capacity. The focus of our current research is to develop a diagnostic mechanism that can be used to improve that capability. The initial conceptual model and research from homeland security has been elaborated into an item bank of diagnostic interview and survey questions. A diagnostic process based on the established practices of organizational development is offered to guide the design and application of tailored assessments. Recommendations are given for the use of the diagnostic process to generate organization- or network-specific data that can guide action planning to improve collaborative capacity.

Introduction

The research presented at this symposium represents the completion of our FY06 activities as well as the plans and progress on the FY07 efforts in the development of a diagnostic method to assess the capacity of organizations to work collaboratively with other organizations. The first phase of the research developed a conceptual model of inter-organizational collaboration, identified factors that enable or inhibit collaboration and established a comprehensive item bank of survey and interview questions that could be used to diagnose the collaborative capacity of an organization or system of organizations. It also outlined a process, based on principles of organizational development, by which the diagnostic results can be used to design interventions to improve collaborative capacity. The second phase, which is in progress, is field testing the items as well as the diagnostic process on interagency partnerships in both the homeland security and acquisition context. The product of Phase Two will be a revised and validated diagnostic instrument and field-validated model for collaborative capacity.

Background

Federal Acquisition Reform has consistently called for more and better collaboration among participating acquisition agencies as well as between the DoD and defense contractors. Specifically, the *DOD Directive 5000.1* (*The Defense Acquisition System*, paragraph E1.2, Collaboration, 2003) specifically states that teaming among warfighters, users, developers, acquirers, technologists, testers, budgeters, and sustainers shall begin during the capability-needs-definition phase of the acquisition lifecycle. Furthermore, the recent *Defense Acquisition Performance Assessment* (*DAPA*) report recommends improved collaboration among acquisition organizations as well as between the DoD and industry. The use of Integrated Product Teams (IPTs), Partnering relationships, and Alpha Contracting processes are a few examples of innovative arrangements being used in some commands. As *DAPA* recommendations are implemented, additional collaboration requirements and opportunities will emerge.

Collaboration across organizations in government and industry has been found to reduce litigation, decrease costs, and increase innovation (Mankin, Cohen & Fitzgerald, 2004). However, experience shows that organizations commonly fail when they attempt to build collaborative relationships. Among the reasons for ineffective collaboration are: diverse missions, goals and incentives that conflict with one another; histories of distrust that are hard to alter; leaders who do not actively support collaborative efforts; and the lack of supportive coordination systems and structures (US Government Accountability Office, 2002, December). However, experience shows that inter-organizational collaboration can be difficult at best. Our research focuses on identifying and assessing those factors that facilitate or inhibit successful collaboration, with the ultimate aim of guiding actions to

enhance the *capacity* of organizations to collaborate with each other when appropriate. We define collaborative capacity as the *ability of organizations to enter into, develop, and sustain inter-organizational systems in pursuit of collective outcomes.*

Development of the Diagnostic Model and Assessment Tool

In a series of studies, beginning with research on homeland security organizations and then reformulated to also address the acquisition context, we have developed a general framework for addressing the problem of how interagency collaborative capacity is developed and maintained (Hocevar, Jansen & Thomas, 2004; Hocevar, Thomas, & Jansen, 2006). The model developed in Phase One of our research program identifies imperatives of successful collaboration and aims to assist organizations in diagnosing their collaborative capacity. The focus of Phase Two was the development of a database of interview and survey questions that can be used to tailor collaborative capacity assessments to specific collaborative contexts. The goal of the diagnostic is to allow organizations to assess their capacity to engage in collaborative efforts and then use the assessment results to identify specific activities to improve their collaborative capacity. The survey and interview questions were developed in conjunction with the five dimensions in our model of interagency collaboration capacity. The dimensions are presented in more detail in Figure 1.

Figure 1. Factors Related to the Development of Collaborative Capacity

Organization dimensions	***"Success" factors that contribute to collaborative capacity***	***"Barriers" that inhibit collaborative capacity***
Purpose & strategy	- "Felt need" to collaborate - Common goal or recognized interdependence - Adaptable to interests of other organizations	- Divergent goals - Focus on local organization over cross-agency (e.g., regional) concerns - Lack of goal clarity - Not adaptable to interests of other organizations
Structure	- Formalized coordination committee or liaison roles - Sufficient authority of participants	- Impeding rules or policies - Inadequate authority of participants - Inadequate resources - Lack of accountability - Lack of formal roles or procedures for managing collaboration
Lateral mechanisms	- Social capital (i.e., interpersonal networks) - Effective communication and information exchange - Technical interoperability	- Lack of familiarity with other organizations - Inadequate communication and information sharing (distrust)

Incentives	- Collaboration as a prerequisite for funding or resources - Leadership support and commitment - Absence of competitive rivalries - Acknowledged benefits of collaboration (e.g., shared resources)	- Competition for resources - Territoriality - Organization-level distrust - Lack of mutual respect - Apathy
People	- Appreciation of others' perspectives - Competencies for collaboration - Trust - Commitment and motivation	- Lack of competency - Arrogance, hostility, animosity

Specific survey and interview questions have been generated for each of the five dimensions of collaborative capacity presented in the figure above. Illustrative questions for each of the dimensions are presented below:

<u>Purpose and Strategy</u> questions address organizational purpose, goals, and values; the degree of perceived "felt need" to collaborate; and strategic planning processes.

- *Interagency collaboration is a high priority for this organization.*
- *We have clearly established goals for interagency collaboration.*
- *We consistently use an interagency approach to planning.*

<u>Collaborative Structure</u> includes policies, roles and responsibilities that facilitate or serve as barriers to collaboration; formal control mechanisms including authority and standard operating procedures; and coordinating structures.

- Our organization is flexible in adapting our procedures to better fit with those of partner organizations.
- My organization has mechanisms in place to monitor and evaluate collaborative efforts.
- Conflicting organizational policies make collaboration very difficult.

<u>Social Capital through Lateral Mechanisms</u> addresses both formal and informal factors, including network ties, information sharing, combined training, and familiarity with other organizations. These factors, working together, can become internalized into a culture of collaboration:

- *Our organization has strong norms that encourage sharing information with other agencies.*
- *Our organization commits adequate human and financial resources to training with other agencies.*
- *Our organization invests time and resources to become familiar with the capabilities and requirements of our partner organizations.*

Incentives address both the factors that encourage and discourage organizational- and individual-level engagement in collaboration. The structure of incentives can shape whether organizations frame their interactions as collaborative or competitive.

- A history of competition and conflict affects our interagency capability.
- Our organization rewards members for their interagency collaborative activities.
- The senior leaders of our organization often discuss the importance of interagency collaboration with others in the organization.

People are the foundation for macro-level collaboration, which ultimately depends on their perceptions, motives, attitudes, and skills.

- *Members of our organization respect the expertise of those in other organizations with whom we have to work.*
- *We have training in place to develop collaborative skills (e.g., conflict management, team-process skills).*
- *People in our organization tend to be suspicious and distrustful of our partners in other organizations.*

We expect that the ability to systematically assess collaborative capacity can contribute to something akin to a common doctrine and common operational picture that will assist leaders in developing action plans for developing this important capability. The diagnostic process encourages a common language and understanding around collaboration and assists leaders in determining capabilities that the organization must develop to be successful. The next section shows how our diagnostic tool can leverage learning for an organization.

Process for Diagnosing Collaborative Capacity

We have shaped the process for using the collaborative capacity diagnostic around the well-established principles of organization development (Beckhard, 1969). The focus in this presentation is how to use the Collaborative Capacity survey instrument to inform leaders and change agents of the strengths and weaknesses of their organization's collaborative systems. From these data, specific interventions can be identified and implemented. The survey tool is, thus, designed to contribute to a learning process that improves interagency relationships.

This approach follows the process of a “gap” analysis (e.g., Harrison, 1994). In consultation with the client organization(s), the diagnostic process identifies the desired future state—why collaboration is needed and ways in which improvements in this capability can be accomplished. Through the dialogue that occurs in the design, conduct, and analysis of survey results, organizational members become sensitized to the importance of the issues being assessed (Downs & Adrian, 2004). The data from the diagnostic survey also provide a mechanism to challenge existing mental models or assumptions of organizational members about inter-organizational collaboration. They provide a common basis for understanding the “current state” and can, thus, motivate desired improvements.

The key question being addressed in interpretation is, “What do the assessment results mean?” In action planning, the question is “What do we do about it?” The organizational members engaged in action planning may be different (or in addition to) those who were involved in the interpretation. It is important to involve members in deciding what action to take if their commitment or capabilities are necessary to the implementation of the action plan. Feedback about the diagnostic process should include not only the results and interpretation of the assessments, but also the interventions identified as part of action planning. Ongoing communication through the implementation of action planning is also important if the diagnostic process is to contribute broadly to organizational learning (Downs & Adrian, 2004; Senge, 1992).

The initial assessment establishes a baseline that can be used to evaluate progress toward the desired goals after the implementation of interventions. The assessment also allows the opportunity for comparisons across organizational levels and units. For example, it may be worthwhile to investigate the extent to which top-level managers’ assessment of collaborative capacity is similar to those of front-line workers. Also of interest could be a comparison of those whose work involves them with counterparts in other organizations/agencies with those who have less frequent contact.

Next steps—Validating the Assessment Tool with Field Testing and Subject-matter Experts (SMEs)

There is a growing body of literature on the concept of a capacity for collaboration, and our results to date coincide with others who are working in this area (e.g., Foster-Fishman, Berkowitz, Lounsbury, Jacobson, & Allen, 2001; Hansen & Nohria, 2004; Huxham, 1996; Mankin, Cohen, & Fitzgerald, 2004). What we add to those pursuing these ideas (e.g., Bardach, 1998) is a way to measure the overarching concept of collaborative capacity and the contributing variables. Generating valid and reliable interview questions and survey items require a painstaking process of refinement, testing and retesting. All questions are to be subjected to critical review by subject-matter experts from the acquisition community as well as from homeland security organizations currently implementing or initiating inter-organizational collaboration. The interagency level of analysis is complex and requires analysis from a variety of possible contexts, forms, structures and processes. Our goal is to develop an audit that is sufficiently generalizable to be conducted in a wide variety of contexts, but it must be specific enough to provide actionable insights to organizational leaders.

In this stage of our research, we are identifying potential partners who are interested in assessing collaborative capacity. These partners will allow us to field test the instrument with organizations that are in different developmental stages. In other words, some

organizations may have only recently initiated the process of collaborating; others may have been collaborating for some time, but face the problems of institutionalizing and formalizing the process; and some may have institutionalized their processes. Different lessons can be learned in each of these contexts.

We should also note that the process of validating items is also a process of validating and elaborating theoretical constructs. This means that the nuts-and-bolts process of revising and interpreting items through field testing itself generates more coherent and useful ways of thinking about the capabilities and capacities of interagency collaboration. For example, we anticipate developing some preliminary hypotheses about the developmental stages of collaborative capacity as we begin our field testing work with organizations that have different amounts of experience with interagency collaboration. We also expect that we will begin to identify somewhat of a hierarchy of predictors of collaborative capacity because it is unlikely that all factors included in our current model are of equal impact in influencing collaboration. As we proceed with our research, we will be developing a more refined diagnostic process, as well as a more refined understanding of how collaborative capacity develops and ways it can be fostered.

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Wednesday, May 16, 2007	**Panel 8 - Implementing Open Architecture**
3:30 p.m. – 5:00 p.m.	**Chair:** **CAPT James Shannon** – Program Manager, Naval Open Architecture, PEO IWS 7.0 **Discussant:** **Thomas (Tom) Huynh**, Associate Professor, Naval Postgraduate School **Papers:** ***Analysis of Modular Open Systems Approach (MOSA) Implementation in Navy Acquisition Programs*** **Rene Rendon**, Naval Postgraduate School ***Software Architecture: Managing Design for Achieving Warfighter Capability*** **Brad Naegle** and **Diana Petross**, Naval Postgraduate School ***Putting Teeth into Open Architectures: Infrastructure for Reducing the Need for Retesting*** **Valdis Berzins** and **Manuel Rodriguez,** Naval Postgraduate School

Chair: CAPT James Shannon – Program Manager, Naval Open Architecture, PEO IWS 7.0, is a native of San Francisco, California and a 1981 graduate of the U. S. Naval Academy in Annapolis, MD where he earned a Bachelor of Science degree. He also received a Master of Science in Telecommunication Systems Management from Naval Post Graduate School, Monterey, CA and a Master of Arts in National Security and Strategic Studies from the College of Naval Warfare, NWC Newport, RI. He attended the Defense Acquisition University in Ft. Belvoir, VA, and is certified Level III in Program Management. Captain Shannon is also a National Security Management Fellow of the Maxwell School of Citizenship and Public Affairs, Syracuse University.

CAPT Shannon's operational experience includes service in the 2nd, 3rd, 5th, and 7th Fleets. He initially served in the Deck and Engineering departments onboard the USS SHASTA (AE-33) homeported in Concord, CA. He was also the Chief Engineer onboard both the USS PEGASUS (PHM-1) in Key West, FL and the USS O'BRIEN (DD-975) in San Diego, CA. CAPT Shannon sailed on several different ships while serving as Material Officer (N4) for COMDESRON 31. The Red Stallions of DESRON 31 relocated to Pearl Harbor, HI during his assignment where they were then known as the Pacific Fleet ASW Squadron as they tested and evaluated various tactics and ASW systems for the Navy. He was the Executive Officer onboard the USS CHANCELLORSVILLE (CG-62) in San Diego, Ca. This ship was awarded the Spokane Trophy for combat readiness during his tour. CAPT Shannon's command tours include the USS ESTOCIN (FFG-15) and USS SAMUEL ELIOT MORISON (FFG-13) in Norfolk, VA. While in command of the ESTOCIN, he deployed to South America in support of Operation UNITAS. The ESTOCIN was recognized for Fleet Retention with the Golden Anchor Award. As the final Commanding Officer of SAMUEL ELIOT MORISON, CAPT Shannon coordinated the transfer of that ship to the Turkish Navy.

Significant shore duties include an instructor tour at the Surface Warfare Officer School in Newport, RI where he taught tactics to prospective Ship Department Heads. He served on the Joint Staff (C4I directorate, J-6) where he was an action officer principally responsible for support of JROC activities. CAPT Shannon was selected as an Acquisition Professional (AP) in 2000. As an AP, he was the Director of Development, Test, and Acceptance of the Evolved SEASPARROW Missile (ESSM). During that assignment, the ESSM successfully passed OPEVAL and received Full Rate Production acceptance by the Service Acquisition Executive (ASN RDA). A plankowner in Program Executive Office, Integrated Warfare Systems (IWS), CAPT Shannon was the first military member assigned to be the Project Manager for NIFC-CA (Naval Integrated Fire Control-Counter Air). He currently serves as the Program Manager for Future Combat Systems Open Architecture (PEO IWS 7) and is responsible for carrying out the open architecture efforts among all warfare systems across the entire Naval Enterprise.

Captain Shannon is married to the former Lisa Palmieri. They have two sons, Patrick and Casey, and one daughter, Caroline. Patrick is a Midshipman at the U.S. Naval Academy ('09).

Analysis of Modular Open Systems Approach (MOSA) Implementation in Navy Acquisition Programs

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Presenter: Rene Rendon, PhD, is on the faculty of the Naval Postgraduate School where he teaches graduate acquisition and contract management courses. Prior to his appointment at the Naval Postgraduate School, he served for more than 22 years as an acquisition and contracting officer in the United States Air Force. His Air Force career included assignments as a contracting officer for major space and weapon systems. Rendon has earned Bachelor, Master's, and Doctorate degrees in Business Administration and has taught for the UCLA Government Contracts program. Dr. Rendon is the Chair of ISM's Federal Acquisition and Subcontract Management Group, a member of the ISM Certification Committee, as well as on the Editorial Review Board for the ISM *Inside Supply Management*. He is a member of the NCMA Board of Advisors, as well as associate editor for its *Journal of Contract Management*. Dr. Rendon has published articles in *Contract Management*, the *Journal of Contract Management*, *Program Manager*, *Project Management Journal*, and *PM Network,* and is co-author of *Contract Management Organizational Assessment Tools* published in 2005.

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Introduction

This research continues the exploration of the use of the modular open systems approach (MOSA) as a method for implementing an evolutionary acquisition strategy in Department of Defense (DoD) programs. The background on the initial DoD and Navy policy on using a MOSA approach in defense acquisition is presented, followed by a review of the initial research findings. A discussion is then provided on the Navy's method for assessing its implementation of a MOSA approach in its acquisition programs. This discussion will focus on the use of the Naval Enterprise Open Architecture Assessment Tool

(OAAT). The primary purpose of this continuing research is to provide an analysis of the results of the OAAT assessment of Navy acquisition programs.

Background on MOSA Policy

DoD 5000.1 states that, “a modular open systems approach shall be employed where feasible” (Under Secretary of Defense (AT&L), 2003, May 12a; 2003, May 12b). Furthermore, in April 2004, the USD (AT&L) issued a memorandum stating, “all programs subject to milestone review shall brief their program’s MOSA implementation status to the Milestone Decision Authority (MDA) to determine compliance” (Under Secretary of Defense (AT&L), 2004, April 5).

Later that year, the Office of the USD(AT&L), Director of Defense Systems, issued instructions for MOSA implementation and identified the Open System Joint Task Force (OSJTF) as the DoD lead for MOSA. This memo also identified MOSA as, “an integral part of the toolset that will help DoD achieve its goal of providing the joint combat capabilities required in the 21st century, including supporting and evolving these capabilities over their total life-cycle” (Under Secretary of Defense (AT&L), 2004, July 7).

In addition, in August 2004, Assistant Secretary of the Navy (Research, Development & Acquisition) (ASN (RDA)) issued a policy statement that developed a single Navy-wide Open Architecture to account for Surface, Air, Submarine, C41, and Space domain unique requirements. That memo also assigned PEO IWS overall responsibility and authority for directing the Navy's OA Enterprise effort. An OA Enterprise Team comprised of OA domain leads, ASN, OPNAV, and SYSCOM representatives was chartered and led by PEO IWS. The Team collectively oversees the development and implementation of the processes, business strategies, and technical solutions which support cross-Enterprise requirements in addition to domain-specific needs. The Enterprise Team will also define an overarching OA acquisition strategy and develop guidance that addresses incentives, intellectual property issues, contracting strategies (i.e., integrator's vs. prime's), and funding alternatives (ASN (RD&A), 2004).

Finally, in a 23 December 2005 letter, Deputy Chief of Naval Operations (Warfare Requirements and Program) established the Navy-wide requirement for OA and laid out the priorities on which it wants Naval OA to focus. The letter, “establishes the requirement to implement Open Architecture (OA) principles across the Navy Enterprise.” It establishes the OA Council (OAC) of representatives of N6/N7 Division

Directors to work with the OAET on the requirements. The letter directs the OAC, PEO IWS 7.0, and the OAET to focus assessment priorities in support of the following capabilities: Track management, Combat ID (CID), Data fusion, Time-critical Targeting & Strike, and Integrated Fire Control (IFC).

Initial Research Findings

The purpose of the initial MOSA research was to explore both the use of the modular open systems approach (MOSA) as a method for implementing an evolutionary acquisition strategy, as well as the implications of using such an approach on the contracting process.

Although the phases of the contracting process are the same for MOSA-based programs as they are for non-MOSA-based programs, this research found that the specific

activities conducted and documents developed during the execution of these contracting phases have a direct influence on the success of a MOSA-based program. For example, the various options for allocating roles and responsibilities between the government and the contractor for the various steps in the acquisition process will influence the amount of "openness" in the program and the contractor's motivation for meeting the desired level of openness.

This research indicated that the greater degree of jointness in acquisition roles and responsibilities, as well as the greater degree of contractor-developed acquisition documents, will lead to a higher level of openness.

This initial research also identified early involvement and participation by industry in developing requirements and acquisition strategy as a key factor in successful MOSA-based programs. Program offices managing a MOSA-based program should conduct extensive market research and industry conferences to achieve this contractor involvement. A best-value contract strategy that is tailored to emphasize technical performance in open-based systems and COTS systems is also a critical factor in meeting higher levels of openness in MOSA-based programs. A contract strategy which involves developing source-selection evaluation factors specifically weighted to emphasize an open systems approach will be critical for MOSA-based programs.

As important as the acquisition strategy is the structure of the contract of a MOSA-based program.

This research identified the use of incentive-fees, award-fees, and award-term contract incentives as integral to the success of MOSA-based programs. These incentives, if structured appropriately, are effective tools for motivating and incentivizing contractors to achieve higher levels of openness in the design and development of systems.

Finally, the consistent and aggressive use of the contractor past-performance information system, as well as the development and establishment of lessons-learned programs and best practices will be essential as more and more MOSA-based programs are initiated. As contractors performing work on MOSA-based programs begin to realize that the DoD is insistent on using open systems in developing its major weapon systems, they should begin to dedicate the required resources to this method of developing weapon systems.

Internal Assessment of MOSA Implementation

The focus of this follow-on research is to analyze the effectiveness of the implementation of MOSA in Navy acquisition programs by investigating the results of MOSA-internal assessments, specifically the results of the Open Architecture Assessment Tool (OAAT). The results of this research will prove beneficial to senior Navy officials by providing data points on MOSA implementation by analyzing the consistency of MOSA compliance status and internal assessments for specific Navy acquisition programs.

The OAAT is a tool designed to assist Navy program managers in assessing the "openness" of their programs. It aligns to the Open Architecture Assessment Model (OAAM) as approved by ASN(RDA) and provides a reproducible and objective method of conducting program assessments. Specifically, the OAAT is an analytic tool that evaluates responses to a set of interrelated questions to provide program officers with an objective and evidence-

based assessment of the degree that a program exhibits openness along two axes: business and technical. The degree that openness is implemented is presented in terms of business/programmatic and technical criteria. The business/programmatic dimension criteria include questions that address: Open Architecture, Modular Open Design, Interface Design and Management, Treatment of Proprietary Elements, Open Business Practices, Peer Review Rights, and Technology Insertion. The technical dimension criteria cover essential OA design tenets of Interoperability, Composability, Reusability, Maintainability and Extensibility.

The OAAT assessment score summary provides a summary of the ratings for each of the evaluated areas (See Figure 1).

Business Areas	**Technical Areas**
Open Systems Approach	**Design Tenet: Interoperability**
Open Architecture	**Design Tenet: Maintainability**
Open Modular Design	**Design Tenet: Extensibility**
Interface Design and Management	**Design Tenet: Composability**
Treatment of Proprietary Elements	**Design Tenet: Reusability**
Open Business Practices	**General Design Tenet**
Peer Review Rights	
Technical Insertion	
Commercial Standards Compliance	

Figure 1. Ratings of Evaluated Areas

In addition, an OA assessment matrix that displays the program current state with respect to business and technical openness is also provided in the assessment summary. Each of these areas (business and technical) is rated on a scale of 0 to 4. (See Figure 2.) The results of the OAAT assessment could then be used by the program manager to help improve the program with respect to Naval Open Architecture.

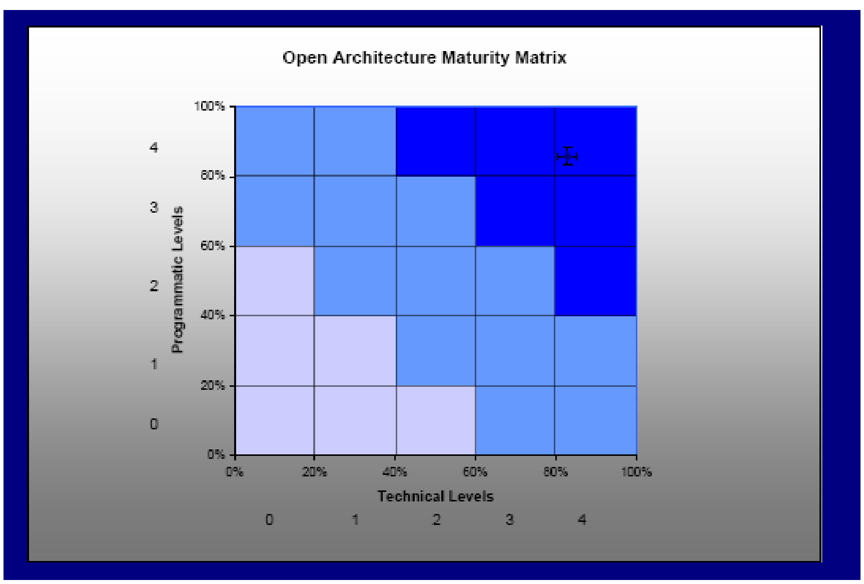

Figure 2. Open Architeture Maturity Matrix

This is an executive summary of the complete research report. The complete research report may be accessed from the Naval Postgraduate School website www.nps.navy.mil/gsbpp/acqn/publications.

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Software Architecture: Managing Design for Achieving Warfighter Capability

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> "Software architecture forms the backbone for any successful software-intensive system. An architecture is the primary carrier of a software system's quality attributes such as performance or reliability. The right architecture—correctly designed to meet its quality requirements, clearly documented, and conscientiously evaluated—is the linchpin for software project success. The wrong one is a recipe for guaranteed disaster" (Software Engineering Institute/Carnegie Mellon, 2007).

Introduction

Software engineers will typically spend 50% or more of the total software development time designing software architecture, and that architecture may provide up to 80% of a modern weapon system's functionality. Increasingly, these systems will operate within a network or other system-of-systems architecture. Obviously, the requirements driving that architectural design effort and the process for tracing requirement to functions, insight into the process, and control of the effort are critical for the successful development of the capability needed by the warfighter.

The DoD typically monitors and controls system technical development through implementation of the Baselines, Audits and Technical Reviews within an overarching Systems Engineering Process (SEP) (Defense Acquisition University, 2004, December, chap. 4). Because of the relatively immature software engineering environment, significantly more analysis and development of the requirements is required. In addition, the software architectural design effort is dependent on in-depth requirements analysis, is resource intensive, and must occur very early in the process. Effective management and implementation of design metrics is essential in developing software that meets the warfighters' needs. This management and metrics effort supplements and supports the system technical development through the Baselines, Audits and Technical Reviews.

There are numerous variations and models of the Systems Engineering Process (SEP). This research uses the model depicted in Figure 1 (below), which illustrates the systems engineering functions described throughout this paper. The concepts are transferable to the SEP "V" model currently used by the DoD.

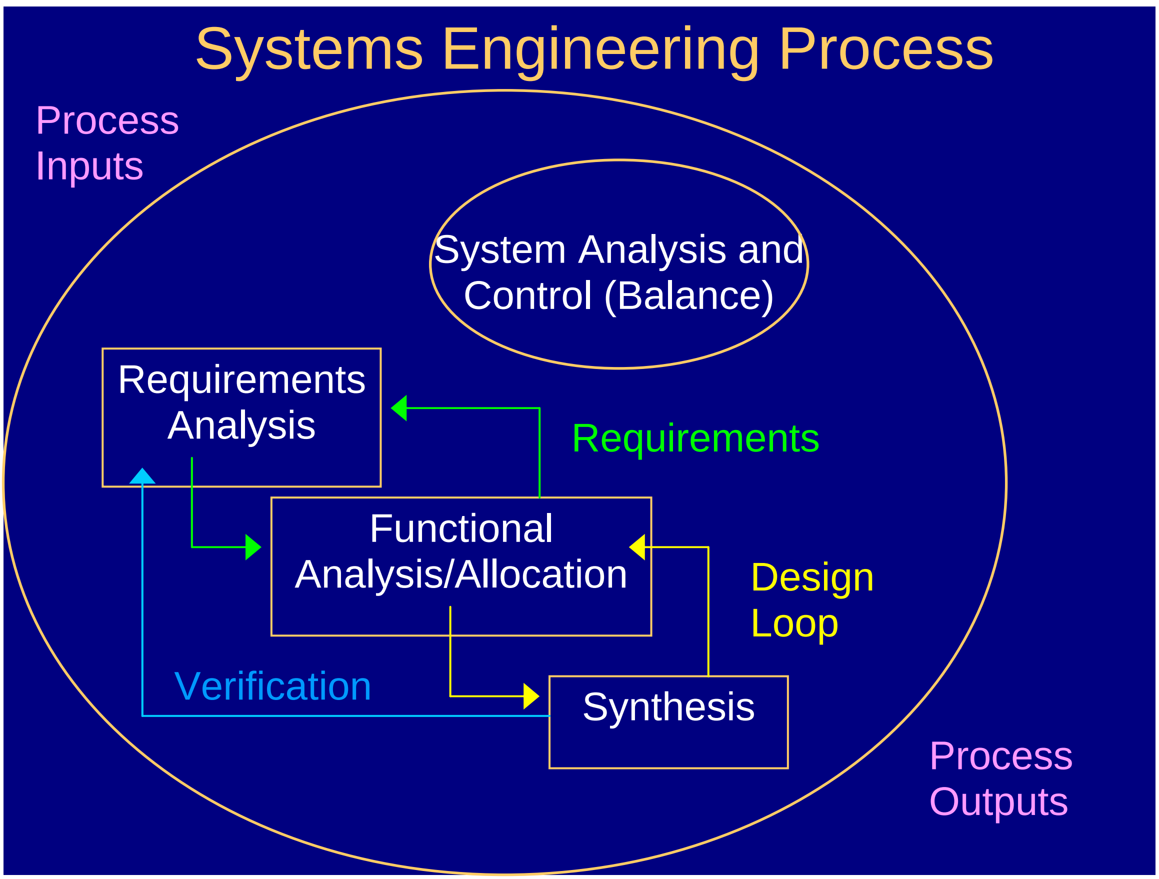

Figure 1. Systems Engineering Process

Software Requirements Impact

The importance of system software requirements development to the potential success of software-intensive systems development cannot be overstated. Underdeveloped, vaguely articulated, ill-defined software requirements elicitation has been linked to poor cost and schedule estimations—resulting in disastrous cost and schedule

overruns. In addition, the resulting products have been lacking important functionality, are unreliable, and have been costly and difficult to effectively sustain (Naegle, 2006, September).

Using the SEP approach, the explicit user capabilities requirements specified in the Joint Capabilities Integration and Development System (JCIDS) provides the Input for system Requirements Analyses. These analyses are intended to illuminate all system-stated, derived and implied requirements and quality attributes necessary to achieve the capabilities needed by the warfighter. The Work Breakdown Structure (WBS) is a methodology for defining ever-increasing levels of performance specificity—using the SEP to guide the development of each successive layer (Department of Defense, 2005, July, pp. 1-5).

Software Engineering Environment

The software engineering environment is not mature, especially when compared to hardware-centric engineering environments. Dr. Philippe Kruchten of the University of British Columbia remarks, "we haven't found the fundamental laws of software that would play the role that the fundamental laws of physics play for other engineering disciplines" (Kruchten, 2005, p. 17). Software engineering is significantly unbounded as there are no physical laws that help define environments; and to date, no industry-wide dominant language, set of engineering tools, techniques, reusable assets, or processes have emerged.

This lack of engineering maturity impacts both requirements development and the subject for this research, design of the architecture, which will be discussed later. To compensate for the relative immaturity of the software engineering environment, the DoD must conduct significantly more in-depth requirements analysis and provide potential software developers detailed performance specifications in all areas of software performance and sustainability.

Performance Specifications and the Work Breakdown Structure (WBS)

Since the implementation of Acquisition Reform in the nineties, detailed specifications have been replaced with performance specifications in order to leverage the considerable experience and expertise available in the defense contractor base. In most hardware-centric engineering disciplines, the expertise the DoD seeks to leverage includes a mature engineering environment in which materials, standards, tools, techniques and processes are widely accepted and implemented by industry leaders. This engineering maturity helps to account for derived and implied requirements not explicitly stated in the performance specification. Three levels of the WBS may provide sufficient detail for a desired system to be developed in a mature engineering environment, such as the automotive field. For example, an automotive design that provides for easy replacement of wear-out items such as tires, filters, belts, and batteries obviously provides sustainability performance that is absolutely required. Most performance specifications do not explicitly address this capability as they would be automatically considered by any competent provider within the mature automotive engineering environment.

In stark comparison, the software engineering environment offers little assistance in compensating for derived and implied requirements, and developers are limited to respond,

almost exclusively, to the explicit requirements provided. The *DoD Handbook 881A*, "Work Breakdown Structures for Defense Materiel Items," recommends a minimum of three levels be developed before handoff to a contractor. If a program is expected to be high-cost or high-risk, it is critical to define the system at a lower level of the WBS (Department of Defense, 2005, July, p. 3). Complex weapon systems are nearly always high-cost, and the complex software development needed almost always means that it is high-risk, as well. The WBS and performance specification must, consequently, be significantly more developed to provide the software engineer enough information and insight to accurately estimate the level of effort needed—cost and schedule—and to actually produce the capabilities needed by the warfighter. Contracts resulting from proposals that are based on underdeveloped, vague, or missing requirements typically result in catastrophic cost and schedule growth as the true level of software development effort is discovered only after contract award.

The WBS provides the basis for the performance specification and is a powerful communications medium with potential contractors as the upper levels provide a functional system breakdown structure from the DoD's perspective. The same WBS continues to be developed by the contractor, eventually providing the detailed breakdown structure, which is the basis for the cost and scheduling estimates provided in the proposals and used in the Earned Value Management (EVM) metrics during execution.

Software Quality Attributes

As the system requirements are developed, software quality attributes are identified and become the basis for designing the software architecture. One methodology for fully developing the software attributes is to use the Software Engineering Institute's Quality Attribute Workshop (QAW), which is implemented before the software architecture has been created and is intended to provide stakeholder input about their needs and expectations from the software (Barbacci, Ellison, Lattanze, Stafford, Weinstock, & Wood, 2003, August, p. 1).

While the QAW would certainly be useful after contract award, conducting the workshop between combat developers/users and the program management office before issuance of the Request for Proposal (RFP) would provide an improved understanding of the requirements, enhance the performance-specification preparation, and improve the ability of the prospective contractors to accurately propose the cost and schedule. This approach would support the goals of the System Requirements Review (SRR), which is designed to ascertain whether all derived and implied requirements have been defined.

The QAW process provides a vehicle for keeping the combat developer and user community involved in the DoD acquisition process, which is a key goal of that process. In addition, the QAW includes scenario-building processes that are essential for the software developer in designing the software system architecture (Barbacci, Ellison, Lattanze, Stafford, Weinstock, & Wood, 2003, August, pp. 9-11). These scenarios will continue to be developed and prioritized after contract award to provide context to the quality attribute. Specific recommendations for this process will be discussed later.

Maintainability, Upgradability, Interoperability/Interfaces, Reliability, and Safety/Security (MUIRS) Analytic Technique

The QAW provides the "how," and the performance requirements (with Maintainability, Upgradability, Interoperability/Interfaces, Reliability, and Safety/Security

(MUIRS) analytic technique) provides the "what"—or at least a significant portion of it. The MUIRS elements also help capture the need for Open Architecture (OA), especially in the Maintainability, Upgradability, and Interoperability/Interfaces elements. Much of the software performance that typically lacks consideration and is not routinely addressed in the software engineering environment can be captured through development and analysis of the MUIRS elements. Analyzing the warfighter requirements in a QAW framework for performance in each MUIRS area will help identify software quality attributes that need to be communicated to potential software contractors (Naegle, 2006, September, pp. 17-24). While this technique would be effective within any system, it is especially effective in compensating for the lack of software engineering maturity and in conveying a more complete understanding of the potential software-development effort, resulting in more realistic proposals.

The MUIRS analytical approach provides a framework to capture, develop, and document derived and implied requirements—which may be vaguely alluded to or missing from the user/combat developer's requirements documents. For example, a user requirement might be simply presented in terms like, "The network must be secure in all modes within the intended environment." Without further development, the software engineer may interpret that requirement in many different ways, planning for authentication and encryption/decryption routines. Applying the Safety/Security analytic approach in a QAW format, the derived and implied requirements are likely to elucidate the following requirements:

- Ability to constantly monitor the network to detect and counteract active or passive intrusion or attacks
- Ability to provide details of attacks to Intelligence/Counter Intelligence personnel
- Ability to conduct passive measures to ensure that all node operations are conducted with authorized personnel exclusively
- Ability to quarantine a suspect node without impacting the rest of the network. Ability to lift the quarantine when properly authenticated.
- Ability to identify information provided to, or requested by the quarantined node for Intelligence/Counter Intelligence analysis
- Passive ability to authenticate information sources
- Ability to interoperate with other secure devices and networks without the risk of compromise
- Ability to accommodate network system changes and upgrades
- Ability to accommodate a wide array of users and organizations, formed into the secure network task force as missions dictate

The difference in the level of requirement development is significant, and the more complete information provides necessary performance thresholds that must be accommodated by the software design and development effort. The software architecture would likely be vastly different the implied and derived security requirements are considered. The amount of work required to meet the actual software security-performance attributes is revealed to the contractor prior to proposal preparation—which should vastly improve the cost and schedule accuracy of the proposal submitted. In addition, the software engineer gains a much more in-depth understanding of the system being developed, thereby improving the design effort described later.

Similar analyses of all MUIRS elements provide a much more complete understanding of requirements and insight into the operational environment envisioned by the warfighter. This level of understanding is absolutely crucial for effective design of the software architecture. If the design effort is started without this level of understanding of the requirement attributes, significant architectural design rework or outright scrapping of early design attempts is inevitable—resulting in increased costs and lengthened schedules.

Software Architecture Characteristics

Software Developer Effort

In past acquisition programs, software development was considered something that could be fielded and then "fixed" after the weapon systems were deployed. The complexity of software, interface problems and the cost for rework were grossly underestimated; the result was costly schedule slips and less-than-desired performance.

When software development was in its infancy in 1968, Alfred M. Peitrasanta at IBM Systems Research Institute wrote:

> Anyone who expects a quick and easy solution to the multi-faced problem of resource estimation is going to be disappointed. The reason is clear; computer program system development is a complex process; the process itself is poorly understood by its practitioners; the phases and functions which comprise the process are influenced by dozens of ill-defined variables; most of the activities within the process are still primarily human rather than mechanical, and therefore prone to all the subjective factors which affect human performance. (Pietrasanta, 1968, pp. 341-346)

After numerous, costly software disasters, we have learned that software development must be a parallel effort with system development within the acquisition framework to ensure that requirements are being met and usable products are being delivered to the warfighter. As the system requirements are defined, the requirements for the software should also be developed concurrently. One critical factor in the software development effort is applying systems engineering discipline to the process and ensuring that discipline is continuous and rigorous throughout the development. Software development has the highest degree of program risk and tends to evolve into a state of turmoil, which is detrimental to the goal of mission-ready software and has a negative impact on cost, schedule and performance.

Software Functionality and Design Architecture

The design of the architecture begins with the description of the system and identifies the functions required for the system to provide the capabilities desired. The required functions will drive the design of the system architecture. System functionality and performance requirements are documented in the Government's Request for Proposal (RFP). The potential contractor must break down those functions and performance requirements and consider Maintainability, Upgradeability, Interfaces/Interoperability, Reliability, Safety, and Security (MUIRSS) in the design-decision process. The MUIRSS analysis will ensure the contractor understands the requirement and will also identify any

limiting factors in the system requirements tradeoffs. The desired functionality and the analysis will drive the system architecture. For software-intensive acquisition programs, it is even more critical that the performance requirements be communicated and understood by the software developer.

Work Breakdown Structure

The Government's requirements and specifications for a new weapon system are detailed in the RFP; this includes a Government-produced Work Breakdown Structure (WBS) to at least three levels. This is known as the Program WBS and is handed off to the contractor to develop a WBS that defines the level of detail required for product development. This contractor-generated product will ensure the system developer understands the program objectives and the products to be delivered in performance of the contract. The WBS details the functionality and performance of the system and provides a baseline to track performance against cost and schedule. For most hardware-centric programs, a WBS for the top three levels of the system under development is usually enough detail to manage the program. Because of the volatile nature of software development, immature software engineering environment, and the potential impact to cost, schedule and risk, the WBS for software intensive programs need to be developed down to Level 5 or lower for a software-intensive program—including system-of-systems (SOS) and net-centric systems development.

Level 1 of the WBS describes the entire project. If the program is a Systems of Systems (SOS) project, Level I becomes that overarching system. The Army Future Combat System (FCS) has a number of platforms that are segments of the total system. Each platform becomes a major segment of that product (Level 2); the software development would then be broken down to Level 6, which identifies software-configuration items.

Using the FCS as an example, Level 1 describes the overall FCS concept and environment. Level 2 details the major product segments of the SOS. With our example of FCS, the Level 2 would be the manned systems, i.e., infantry-carrier vehicles, command-and-controlled vehicles, mounted combat systems, etc.

Level 3 defines the major components or subsets of Level 2. For software development, decomposing the software WBS to the lowest component is critical for the developer to fully comprehend the detailed level of effort required to design and develop effective systems. Under the FCS scenario, Level 3 would be one of the subsystems on board the manned systems, e.g., the fire-control systems and environmental-control systems. It is clear that WBS definition to this level provides only a very top-level insight to the system being developed; thus, for the software-intensive system, the WBS fails to convey enough information for the contractor to propose a realistic cost and schedule estimate. Too much of the software development work is hidden at this level.

Level 4 becomes a breakout of the component parts of the subsystem. Using a manned vehicle in the FCS program, Level 5 of the WBS would identify the component functions for the fire-control system: for example, detect the target, aim at the target and fire

the munitions. The software build set would support the functionality of that component within the subsystem. Again, using FCS as the overarching program, Level 6 is a sum of software items (SI's) which satisfy a required function and are designated for configuration management. If the software requirements or attributes are well defined, the result is a product that is properly designed to functionally perform to the users' requirements.   Further development below Level 6 may be necessary to adequately convey the derived and implied requirements needed by the software developer.

Systems Engineering Process

Just as it supports hardware development, the Systems Engineering Process (SEP) is essential in the development of software design. In software development, good quality and predictable results are paramount goals in creating the specified warfighter capabilities within cost and schedule constraints. To accomplish those goals, we examine the methods, tools and processes that the software developer uses in building the software with the intent of attaining a product that provides all of the necessary functionality and is supportable, efficient, reliable and easy to upgrade.

The SEP also helps identify and manage program risk. How mature is the processes of the software developer? One cause for delays and cost overruns in the C-17 Globemaster program was the contractor's lack of software experience, which is an element of the developer's maturity. To address developer maturity, SEI developed an evaluation tool in the mid-1980s known as the Capability Maturity Model (CMM) which rates software developers on key elements of maturity including experience, processes, management and demonstrated predictability. This gives the DoD insight into the maturity of potential developers as a means of risk reduction.

The system requirements, stated in the RFP, detail the software's functions, what it must do and how well, under what conditions, and identifies interfaces and interoperability requirements. The performance requirements are also analyzed for required response time, maintainability and modularity, open-architecture requirements and transportability. This phase of the SEP also addresses any restricting factors—for example, interface with legacy systems, any required operating systems—and also identifies issues such as data and software rights constraints.

The developer then identifies software attributes and decomposes functions to the lowest level, ensuring that each performance specification in the RFP has, as a minimum, one function. The functional architecture, the block diagrams and software interfaces are described during this step.

These functions are then combined into a system that describes the architecture, defines all interfaces, explains operating parameters,   produces the SI's and develops the documentation, technical manuals, and any deliverable media (Kazman, Klein & Clements, 2000, August, p. vii).

Attribute-driven Design

"Quality attribute goals, by themselves, are not definitive enough either for design or for evaluation" (Barbacci, Ellison, Lattanze, Stafford, Weinstock, & Wood, 2003, August, p. 3)

The design of the system architecture will be driven by the quality attributes requirements. The performance goals of the system must be defined not only in attributes or qualities, but also in how those attributes interact or interface with the system and subsystems. If those attributes are poorly communicated, the architectural design will fail to meet the performance goals and could potentially impact the overall program cost and schedule. Those critical attributes or qualities must be carefully documented and articulated to the software designer. To evaluate the architecture, the designer must receive a detailed description of the desired attributes with the overall proposed design of the system. However, in the evaluation of the design, an analysis of the attributes may not be enough detail for the developer. The RFP or performance specification needs to address any operational requirements or constraints. Clearly, understanding the attributes in the context of how they are used is critical for the software designer.

Software Architecture Analysis

> If a software architecture is a key business asset for an organization, the architectural analysis must also be a key practice for that organization. Why? Because architectures are complex and involve many design tradeoffs. Without undertaking a formal analysis process, the organization cannot ensure that the architectural decisions made—particularly those which affect the achievement of quality attributes such as performance, availability, security, and modifiability—are advisable ones that appropriately mitigate risks. (Kazman, Klein & Clements, 2000, August, p. vii)

This quote from the Software Engineering Institute illustrates the importance of performing architectural analysis in developing software-intensive systems.

After thorough requirements development and elicitation, architectural analysis is the next necessary step in managing the software development and serves as the SEP functional allocation step. Defining the requirements and software quality attributes is a critical first step to any program development and provides the basis for architectural analysis. One of the main functions of the architectural analyses is to understand how the quality attribute is being achieved by the design architecture and, just as importantly, is to gain insight into how those attributes interact with each other. For example, it is crucial to understand how security is ensured while the open-system architecture the DoD requires is maintained.

Understanding Quality Attributes in Context

It is not sufficient to understand a quality attribute without understanding the context in which it will be used and sustained by the warfighter. One method of gaining the needed context is to develop operational scenarios that would place all software quality attributes into system-use cases spanning key effectiveness and suitability issues. The development and prioritization of the operational scenarios must be accomplished by the user, combat developer, warfighter, and other stakeholders—keeping them actively engaged in the developmental process.

The context in which the attributes function provides significant design cues to the software engineer. For example, the M1A2 Abrams main battle tank uses numerous inputs for precisely engaging threat targets. Several such inputs are essential for any acceptable probability of hitting the desired target, including target acquisition (finding the target),

location (azimuth and range), aiming/tracking, and firing the projectile. To increase accuracy, several other systems are employed that enhance one or more of the essential functions, including cross-wind sensor, temperature sensor, muzzle-reference system, and others. The tank main-gun engagement scenario separates the essential functions from the enhancing functions, allowing the software engineer to design the software to permit an engagement when all of the essential functions are operational—even when an enhancing function, like the temperature sensor, is not working. The warfighter can continue to fight effectively using the system, increasing mission reliability. Without development of these scenarios, every requirement and quality attribute appear to be in the “essential” category, which may result in a design that precludes critical operations when a non-essential enhancing system is not working.

Operational Scenario Development

A scenario is a short statement describing an interaction of one of the stakeholders with the system (Kazman, Klein & Clements, 2000, August, p. 13). A warfighter would describe using the system to perform a task or mission in a range of environments (dark, cold hot, contaminated, etc.). A leader would describe system employment in concert with other joint and allied systems in a system-of-systems approach. A system maintainer would describe preventative or restorative maintenance tasks and procedures. A trainer would describe programs of instruction to task, condition and standard.

Much of the necessary operational scenario development work has been accomplished through implementation of the Joint Capabilities Integration and Development System (JCIDS) (Chairman of the Joint Chiefs of Staff, 2005, May). JCIDS is the user’s capability-based requirements generation process, providing a top-down baseline for identifying future capabilities. It uses a Concept of Operations (CONOPS) analysis technique to assess current systems’ and programs’ abilities to provide the warfighter with capabilities to accomplish missions envisioned in the applicable CONOPS. These CONOPS provide the basis for operational scenario development.

Two of the JCIDS key documents, the Capabilities Design Document (CDD) and Capabilities Production Document (CPD):

> state the operational and support-related performance attributes of a system that provide the desired capability required by the warfighter, attributes so significant that they must be verified by testing and evaluation. The documents shall designate the specific attributes considered essential to the development of an effective military capability and those attributes that make significant contribution to the key characteristics as defined in the [Joint Operations Concepts] JOpsC as [Key Performance Parameters] KPPs. (Chairman of the Joint Chiefs of Staff, 2005, May, p. A-17)

Key system attributes within the context of the CONOPS are the genesis of scenario building and will help guide the user in developing a prioritized set of operational scenarios considered essential in designing the software architecture.

Failure Modes and Effects Criticality Analysis (FMECA)

Failure Modes and Effects Criticality Analysis (FMECA) is a type of exploratory scenario analysis designed to expose potential failure modes and their impact on the system functionality and mission accomplishment. Scenarios are developed that explore system operations in likely or critical subsystem failure modes; then, the criticality of those failures is

analyzed. Operations in degraded modes are also analyzed to gain insight into graceful degradation capabilities as subsystems fail and the system is reduced to ever-decreasing levels of basic functionality. With up to 80% of weapon-system functionality in the system software, it is critical for the design engineer to understand warfighter needs and expectations in these failure modes.

FMECA scenarios with the software systems and subsystems provide architectural design cues to software engineers. These scenarios provide analysis for designing redundant systems for mission-critical elements, “safe mode” operations for survivability- and safety-related systems, and drive the software engineer to conduct “what if” analyses with a superior understanding of failure-mode scenarios. For example, nearly all military aircraft are “fly-by-wire,” with no physical connection between the pilot controls and the aircraft-control surfaces, so basic software avionic functions must be provided in the event of damage or power-loss situations to give the pilot the ability to perform basic flight and navigation functions. Obviously, this would be a major design driver for the software architect.

Architectural Trade-off Analysis SM

The Software Engineering Institute’s Architectural Trade-off Analysis Methodology SM (ATAM) is an architectural analysis tool designed to evaluate design decisions based on the quality attribute requirements of the system being developed. The methodology is a process for determining whether the quality attributes are achievable by the architecture as it has been conceived before enormous resources have been committed to that design. One of the main goals is to gain insight into how the quality attributes trade off against each other (Kazman, Klein & Clements, 2000, August, p. 1).

Within the Systems Engineering Process (SEP), the ATAM provides the critical Requirements Loop process, tracing each requirement or quality attribute to corresponding functions reflected in the software architectural design. Whether ATAM or another analysis technique is used, this critical SEP process must be performed to ensure that functional- or object-oriented designs meet all stated, derived, and implied warfighter requirements. In complex systems development such as weapon systems, half or more than half of the total software development effort will be expended in the architectural design process. Therefore, the DoD Program Managers must ensure that the design is addressing requirements in context and that the resulting architecture has a high probability of producing the warfighters’ capabilities described in the JCIDS documents.

The ATAM focuses on quality attribute requirements, so it is critical to have precise characterizations for each. To characterize a quality attribute, the following questions must be answered:

- What are the stimuli to which the architecture must respond?
- What is the measurable or observable manifestation of the quality attribute by which its achievement is judged?
- What are the key architectural decisions that impact achieving the attribute requirement? (2000, p. 5)

The scenarios are a key to providing the necessary information to answer the first two questions, driving the software engineer to design the architecture to answer the third.

The ATAM uses three types of scenarios: *Use-case scenarios* involve typical uses of the system to help understand quality attributes in the operational context; *growth scenarios* involve anticipated upgrades, added interfaces supporting system-of-systems development, and other maturity needs; and *exploratory scenarios* involve extreme conditions and system stressors, including FMECA scenarios (2000, pp. 13-15). As depicted in Figure 2, below, the scenarios build on the basis provided in the JCIDS documents and requirements developed through the QAW process. These processes lend themselves to development in an Integrated Product Team (IPT) environment led by the user/combat developer and including all of the system's stakeholders. The IPT products will include a set of scenarios, prioritized by the needs of the warfighter for capability. The prioritization process provides a basis for architecture tradeoff analyses. When fully developed and prioritized, the scenarios provide a more complete understanding of requirements and quality attributes in context with the operation and support of the system over its lifecycle.

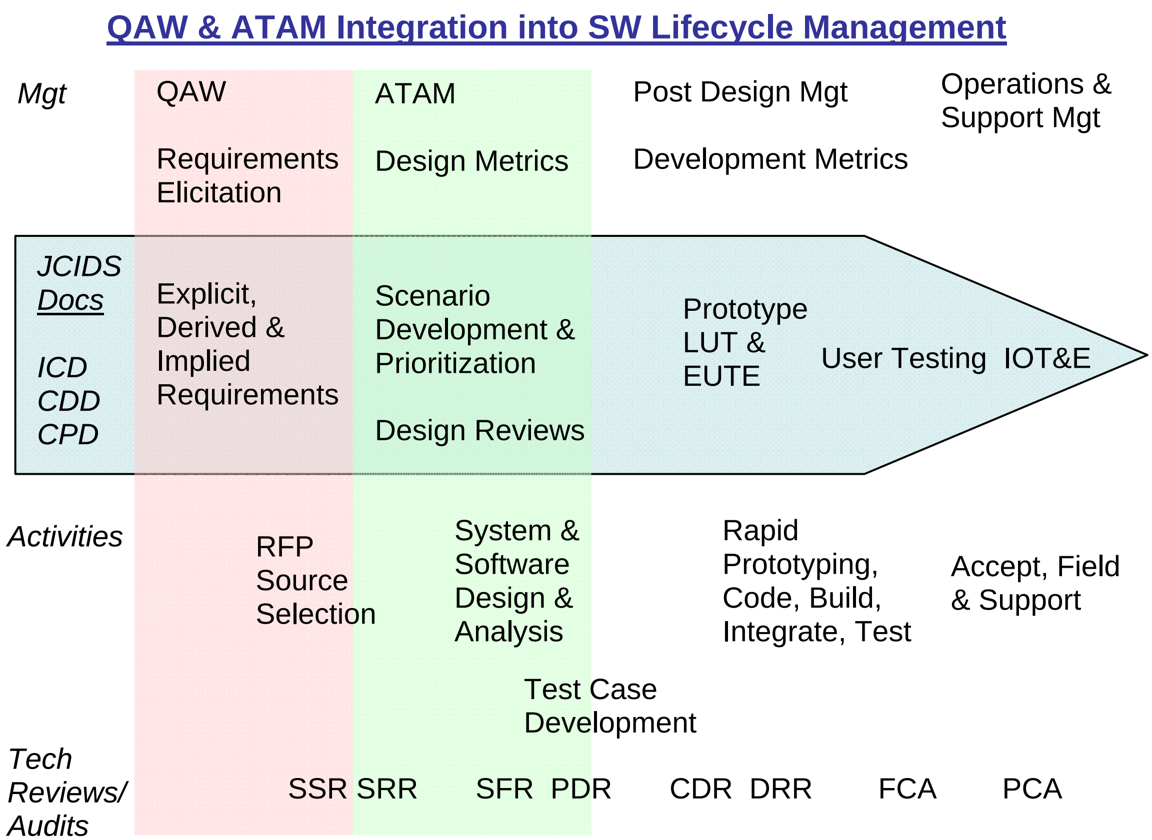

Figure 2. QAW & ATAM Integration into Software Lifecycle Management

Just as the QAW process provides a methodology supporting RFP and Source-selection activities, the Software Specification and System Requirements Reviews (SSR and SRR), the ATAM provides a methodology supporting design analyses, test program activities, the System Functional and Preliminary Design Reviews (SFR and PDR). The

QAW and ATAM methodologies are probably not the only effective methods supporting software development efforts, but they fit particularly well with the DoD's goals, models and SEP emphasis. The user/combat developer (blue arrow block in Figure 2, above) is kept actively involved throughout the development process—providing key insights the software developer needs to successfully develop warfighter capabilities in a sustainable design for long-term effectiveness and suitability. The system development activities are conducted with superior understanding and clarity, reducing scrap and rework, and saving cost and schedule. The technical reviews and audits (part of the DoD overarching SEP) are supported with methodologies that enhance the visibility of the development work that is needed and the progress toward completing it.

One of the main goals in analyzing the scenarios is to find key architectural decision points that pose risk for meeting quality requirements. Sensitivity points are determined, such as real-time latency performance shortfalls in target tracking. Tradeoff points are also examined, such as level of encryption and message-processing time. The Software Engineering Institute explains, "Tradeoff points are the most critical decisions that one can make in an architecture, which is why we focus on them so carefully" (Kazman, Klein & Clements, 2000, August, p. 23).

The ATAM provides an analysis methodology that compliments and enhances many of the key DoD acquisition processes. It provides the requirements loop analysis in the SEP, extends the user/stakeholder JCIDS involvement through scenario development, provides informed architectural tradeoff analyses, and vastly improves the software developer's understanding of the quality requirements in context. Architectural risk is significantly reduced, and the software architecture presented at the Preliminary Design Review (PDR) is likely to have a much higher probability of meeting the warfighters' need for capability.

Test-case Development

A significant product resulting from the ATAM is the development of test cases correlating to the use case, growth, and exploratory scenarios developed and prioritized. Figure 3, below, depicts the progression from user-stated capability requirements in the JCIDS documents to the ATAM scenario development, and finally to the corresponding test cases developed. The linkage to the user requirements is very strong as the user documents drive the development of the three types of scenarios, and in turn, the scenarios drive the development of the use cases. The prioritization of the scenarios from user-stated Key Performance Parameters (KPPs), Critical Operational Issues (COIs), and FMECA analysis flows to the test cases, helping to create a system test program designed to focus on effectiveness and suitability tests—culminating in the system Operational Test and Evaluation (OT&E).

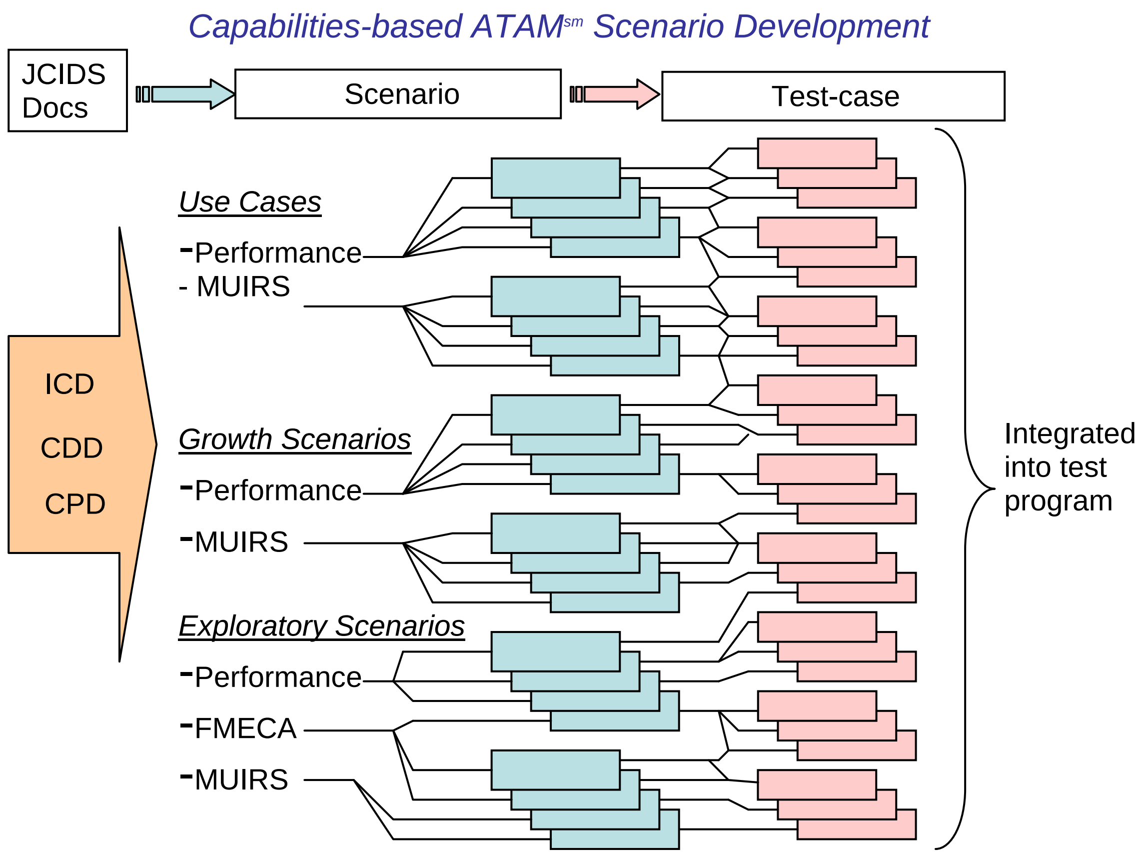

Figure 3. Capabilities-based ATAM Scenario Development

The software developer's understanding of the eventual performance required to be considered successful guides the design of the architecture and every step of the software development, coding, and testing through to the Full Operational Capability (FOC) delivery and OT&E. Coding and early testing of software units and configuration items is much more purposeful due to this level of understanding.

The resulting test program is very comprehensive as each prioritized scenario requires testing or other verification methodologies to demonstrate how the software performs in each related scenario and satisfies the quality attributes borne of the user requirements. The testing supports the SEP design loop by verifying that the software performs the functions allocated to it and in aggregate, performs the verification loop process by demonstrating that the final product produces the capability identified in the user requirements through operational testing.

Architectural Analysis Products

Architecture Documentation and the Preliminary Design Review (PDR)

One of the main purposes of the PDR is to evaluate the system architectural design before committing significant resources to the construction of the system. It is a key review

in the SEP as it provides traceability from the requirements to the functional allocation of the proposed design.

It is critical to have a complete functional- or object-oriented Software Design Document reviewed at the PDR. Given that, the software developer would likely have spent 50% or more of the effort at the time of the PDR for a software-intensive system. Discovering that the proposed software design is insufficient at this point in the development cycle can be disastrous to the budget and schedule for the entire program, especially if the proposed design must be scrapped or if there is significant redesign required.

Architecture Documentation

Documenting the process decisions in designing the software architecture provides a record of design decisions, tradeoffs made, and priorities implemented throughout the design effort and design reviews. The active involvement of the user and all system stakeholders throughout this process is one of the keys to achieving a robust design that provides warfighter capabilities and long-term, cost-effective sustainability. The ATAM provides methodologies that formalize the stakeholder participation in the architectural design.

The ATAM would help drive documentation from quality attributes to both the three types of prioritized scenarios as well as the test cases needed to demonstrate or verify performance. The quality attributes are understood in the context of the user-prioritized scenarios, so design decisions have strong linkage to user priorities. The test cases help guide the design effort as the software engineer has a very clear understanding of what the software must do, under what conditions, and to what standard. Design reviews each have a clearly defined focus, with the ATAM products providing a common understanding of what is to be accomplished.

Scenario Inventory

One of the main products resulting from the ATAM is the prioritized inventory of use case, growth, and exploratory scenarios that drive the architectural design. As the user (along with other stakeholders) is the primary source for scenario development, the resulting design is user-oriented, not engineer-oriented.

The prioritization of the scenarios provides the basis for tradeoff analyses and design decisions, placing tradeoff decisions where they should be—with the warfighter. With the user involved throughout the design process, the resulting system is much more likely to satisfy warfighter capability requirements.

Software and System Test Program

The development of test cases from the scenarios, as depicted in Figure 3 above, provides the Design Loop function of the SEP by ensuring that the software developed performs the functions defined by the scenarios, which represent the quality attribute requirements in context. The inventories of test cases are developed from the user-defined scenarios so that there is one or more test case for every scenario. The test cases will tend to satisfy both technical issues (as the software developed will be tested against its intended function) as well as operational issues, as each function is borne of the users' scenarios.

The aggregated test cases are part of the system's overall test program and contribute to readiness for the Initial Operational Test and Evaluation (IOT&E). The IOT&E is the defining event in the SEP Verification Loop, ensuring that the software developed satisfies user effectiveness and suitability requirements and meets warfighter capability needs specified in the JCIDS documents.

Software Design Metrics

From the DoD's point of view, gaining insight and control of the software design process is crucial to delivering the warfighter capabilities required. In addition, metrics provide a means to monitor and control the process. The metrics chosen must provide the DoD insight into how the software architecture is designed to satisfy quality attributes and requirements across a broad spectrum of functionality and long-term sustainability performance. In addition, technically oriented design metrics such as complexity are also important, but are not the focus of this research.

The system architectural design is very much a shared responsibility between the DoD and the software developer, so metrics must also reflect developmental measures spanning both. For instance, designating the completed set of prioritized scenarios as a design metric involves measuring the build of the scenarios in a collaborative user/stakeholder/developer environment.

Using the completion of the ATAM products as metrics is logical as they are measurable, are key processes in the architectural design, and serve as indicators to the progress towards successfully completing the design process. Useful ATAM-based metrics would include:

- Business Drivers Developed
- Prioritized Scenario Sets Developed
- Attribute Utility Tree
- Sensitivity Points & Tradeoff Points
- Architecture Approach Document

Summary

The main goal of the DoD acquisition process is to develop identified warfighter capabilities within predicted and controlled timelines and cost targets; yet, many software-intensive systems developed have experienced significant cost and schedule growth due, at least in part, to the software development component. There are many factors that contribute to the problem—including how and when the DoD conveys the needed quality attribute requirements.

The DoD acquisition model uses the Systems Engineering Process (SEP) as the central process for controlling the developmental process of its systems. The SEP is an integrated process with the DoD and the contractors selected, thereby urging shared responsibility for effective systems development. The process begins and ends with the user or combat developer responsible for providing the capabilities-based requirements, which are further developed and decomposed by the Program Manager and contractors responsible for building the system. The system components are constructed, integrated and continually tested, culminating in the User's acceptance testing, usually the Initial Operational Test and Evaluation (IOT&E).

A key to the SEP implementation is effective and complete development and communication of the system requirements. This must happen at some point for any system to be successfully developed; but *when* it happens is extremely important to the cost and schedule estimate accuracy. When the contractor has a good understanding of the work to be completed from the requirements presented, more accurate estimates are offered in the contractor's proposal before the program schedule is locked in with a contract. If a significant portion of the work is discovered through requirements decomposition *after* the contract is in place (typical of software components), the estimates provided in the proposal are severely understated, and the program schedule and budgets are no longer appropriate.

One reason the software component is more sensitive to the requirements development is that the software engineering environment is immature when compared to most hardware-centric environments. Vague or missing requirements for a hardware item may be compensated by a mature engineering environment that accommodates implied requirements. For instance, the automotive industry would provide the ability to easily replace normal wear-out items like filters and tires, whether or not such provisions were specified. The software engineering environment does not offer that level of maturity.

The MUIRS analytical technique helps capture software performance requirements that are routinely overlooked in the immature software engineering environment. The MUIRS analysis helps capture and convey Open Architecture needs, safety and security considerations, and long-term supportability performance needed by the warfighter.

In addition to simply understanding the breadth of system requirements, the software engineer needs to understand them in context of the operations, supportability, and environments to design a software architecture that is effective. It is not enough to understand what the software must do; the engineer must understand under what circumstances, in what environments, and to what standard the function must be performed.

What the DoD needs to improve the acquisition of software-intensive systems are methodologies that capture and convey quality attribute requirements in an operational context, within a Systems Engineering Process environment. The Software Engineering Institute's Quality Attribute Workshop (QAW) and Architecture Tradeoff Analysis Methodology SM (ATAM) provide well-suited techniques for developing requirements in context. The QAW process before contracting helps provide enough requirements elicitation for more accurate contractor proposals; likewise, the ATAM helps provide the operational context through scenario and test-case development before the software design effort. Both products support the SEP, providing methodologies for performing critical SEP functions.

DoD personnel (user/combat developer and Program Manager/materiel developer) are key and integral to the development of effective and suitable warfighter capabilities within predictable cost and schedule parameters. Improving the processes that develop and convey system quality attribute requirements in context will improve the cost, schedule and performance predictability of software-intensive systems and will reduce the supportability costs over the life of the system.

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Putting Teeth into Open Architectures: Infrastructure for Reducing the Need for Retesting

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Abstract

The Navy is currently implementing the open-architecture framework for developing joint interoperable systems that adapt and exploit open-system design principles and architectures. This raises concerns about how to practically achieve dependability in software-intensive systems with many possible configurations when: 1) the actual configuration of the system is subject to frequent and possibly rapid change, and 2) the environment of typical reusable subsystems is variable and unpredictable. Our preliminary investigations indicate that current methods for achieving dependability in open architectures are insufficient. Conventional methods for testing are suited for stovepipe systems and depend strongly on the assumptions that the environment of a typical system is fixed and known in detail to the quality-assurance team at test and evaluation time. This paper outlines new approaches to quality assurance and testing that are better suited for providing affordable reliability in open architectures, and explains some of the additional technical features that an Open Architecture must have in order to become a Dependable Open Architecture.

Introduction

The Navy's Open Architecture (OA) is defined to be a multi-faceted strategy providing a framework for developing joint interoperable systems that adapt and exploit open-system design principles and architectures (DAU, 2007b). The objective of supporting adaptable systems has significant implications for quality assurance. OA approaches often involve: (i) a public, non-proprietary architecture that can accept plug-in components and be transparent to changes (e.g., the system should continue to work if selected components or connectors are replaced by different components or connectors), and (ii) an architecture whose purpose is to make explicit the common interfaces (e.g., POSIX, CORBA, etc.). Main goals of Navy's OA include minimizing total cost of ownership, increasing competition, achieving reuse, optimizing systems, and developing systems that support evolution.

This paper explores some test and evaluation implications, outlines an approach for providing affordable quality assurance in the kind of dynamic environment that open architectures are intended to accommodate, and evaluates the current state of some technologies that support the new approach.

The Navy's requirements to implement OA are set forth in several Department of Defense (DoD) and Department of Navy (DoN, 2004, August 5) policy documents (e.g., "The

Defense Acquisition System" (DoD, 2003, May 12), "Guidance Regarding Modular Open Systems Approach (MOSA) Implementation" (DoD, 2004, April 5), "Naval Open Architecture Scope and Responsibilities" (DoN, 2004, August 5), etc.). In the past the Navy has acquired systems that, although they performed their functions and tasks exceedingly well, were unique in their designs and engineering. Indeed, they required unique parts, equipment, and services to support them, were supported by a limited number of suppliers and became unaffordable to maintain. There are numerous instances, moreover, in which a system or platform was scrapped rather than upgraded or modernized because the cost to do so had become prohibitive. Test and evaluation account for an appreciable part of the cost for system upgrades. This paper explores how open architecture principles can be extended and applied to reduce these costs and to make Navy systems more agile.

Business issues are pushing the Navy to shift its development processes towards an open-architecture paradigm. In an era of strenuous competition for dollars, the Navy is continuously challenged with budget decisions. Inflexible acquisition strategies lock the Navy into single systems and vendors that limit the service's options for competition and innovation. Limited competition impedes innovation, while OA provides options for greater competition and inclusion of innovators. Cost of procured systems is due to maintenance as well as development expense. Stovepiped processes lead to acquisition of systems across the Navy with duplicated capabilities. For example, every ship (class) had a unique combat system. Currently, limited asset reuse takes place across the enterprise without open architectures. However, there are few enterprise processes to foster integration in a legacy environment. To achieve rapid fielding of new technology and capability for the Fleet, the Navy's business model has to change from the classic acquisition system to a process that supports Rapid Capability Insertion. Open architecture meets those needs by shortening cycle-times for getting capability to the warfighter when needed. The use of modular systems to facilitate technology refreshment and obsolescence mitigation is a key aspect of OA. Increased competition and innovation are possible through changed business practices enabled by OA.

Many technical issues are also motivating the Navy's change towards open architectures:

- Procurement of monolithic systems using legacy processes produces incompatible systems that are not interoperable.
- Software closely coupled (integral) to the computing hardware platforms is not reusable.
- Special-use code and modules that cannot be reused across the Navy are artifacts of the legacy approach to systems acquisition.
- Proliferation (and resulting lifecycle cost growth) of hardware and software baselines results from upgrade processes in closed systems.

Consequently, there has been much attention to cultural issues and acquisition policies to facilitate adoption of an open architecture paradigm for Navy systems.

This paper addresses a complementary effort to identify current weaknesses and gaps in the state of the knowledge with respect to assuring reliability of DoD/DoN systems developed according to open-systems principles, and to develop or adapt new methods for overcoming those weaknesses so they can be used in Navy open architectures. We are

studying weaknesses in current best practices with respect to the context identified above, and are performing research to extend and develop methods to overcome those weaknesses.

Our preliminary investigations indicate that current methods for achieving dependability in open architectures are insufficient. The main problem is how to practically achieve dependability in software-intensive systems with many possible configurations when the actual configuration of the system is subject to frequent and possibly rapid change, and the environment of typical reusable subsystems is variable (used in many platforms) and unpredictable (mission-dependent). This is a major problem for practical development because real development projects depend heavily on software testing, which is strongly context-dependent. Conventional methods for testing depend strongly on the assumptions that the environment of a typical system is fixed and known in detail to the quality-assurance team at test and evaluation time. These assumptions are quite reasonable for stovepipe systems but are not valid for open architectures. A component in an open architecture should be reusable not only across current classes of ships but also across future platforms that are yet to be designed—those that belong to different services, and perhaps even to coalition partners. This set of contexts is very large in practice, is open-ended, and cannot even in principle be known in detail to the test and evaluation team.

This paper outlines new approaches to quality assurance and testing that are better suited for providing affordable reliability in open architectures, and explains some of the additional technical features that an Open Architecture must have in order to become a Dependable Open Architecture, i.e., one that can support reuse and rapid reconfiguration via module swapping (without compromising reliability) while remaining economically viable at the level of individual systems and reducing total ownership cost for the enterprise. This requires linking the architecture with: 1) specific dependability requirements, 2) certifiable technical standards for each interaction path, 3) specialized types of testing, as well as combining that testing with other kinds of computer-aided quality-assurance methods. The paper explains the concepts behind the approach and why it is expected to work as claimed.

Navy's Vision of Open Architecture

The Navy Open Architecture (Navy OA) is a Navy initiative for a multi-faceted strategy providing a framework for developing joint interoperable systems that adapt and exploit open-system design principles and architectures (DAU, 2007a, DAU, 2007b). This is a systems design approach consistent with several governmental concepts and initiatives, such as the Open Architecture Computing Environment (OACE) (Naval Sea Systems Command, 2007), FORCEnet (FORCEnet, 2007a), and the Modular Open Systems Approach (MOSA) (Open Systems Joint Task Force, 2007). OACE seeks to ease the test and evaluation burden by limiting hardware choices to certain approved possibilities. FORCEnet is an operational concept that can benefit from realization of OA goals for its implementation. MOSA is a joint-acquisition approach that shares many of the goals of the Navy's OA effort.

The OACE (NSWCDD, 2004, August 23a, NSWCDD, 2004, August 23b) aims to implement open specifications for interfaces, services and supporting formats. It enables software components to work across a range of systems and interoperate with other software components on local and remote systems. Thus, the OACE framework includes a set of principles, processes, and best practices. The OACE is a surface-Navy approach to setting technical standards for shipboard systems. It shares many of the objectives of OA,

but does not address business processes that deal with those objectives, and does not apply to submarines, aircraft or C4I systems. The OACE consists of a set of documentation describing an infrastructure of technologies supported by a reference architecture. This infrastructure includes cable plant, cabinets, network components, processors, operating systems, adaptation and distribution middleware, frameworks, resource management, common services (e.g., system server applications such as web servers), etc. As an example, Figure 1 shows the reference OA defined by the OACE.

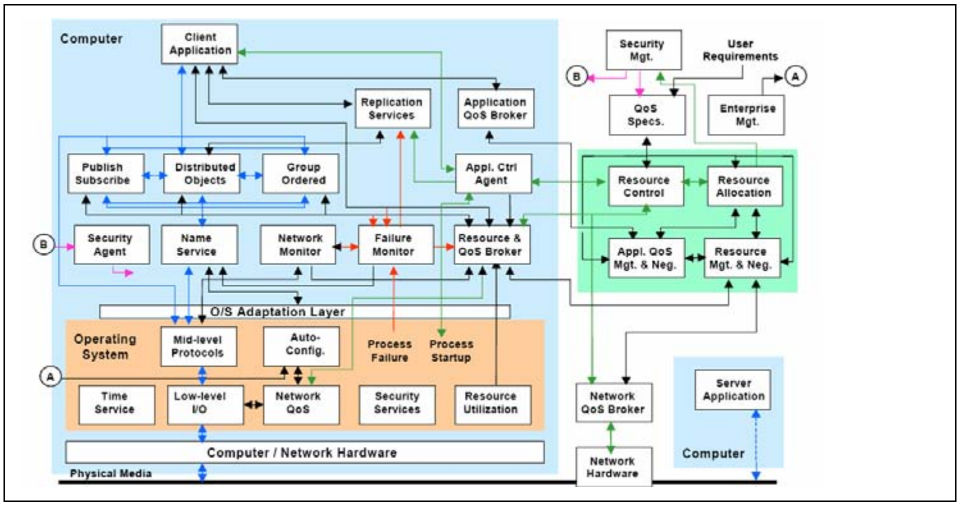

Figure 1. The OACE's Open Architecture Computing Environment
(extracted from NSWCDD, 2004, August 23a)

The OACE also defines guidance and strategies for fault tolerance, scalability, portability, real-time performance, system composition, system test & certification, and selection of standards (e.g., POSIX, CORBA, etc.). The OACE will allow the Navy to introduce and change out commercial technology to maximize affordability and performance goals.

FORCEnet is the operational construct and architectural framework for Naval Warfare in the Information Age to integrate warriors, sensors, networks, command and control, systems, platforms, and weapons into a networked, distributed combat force, scalable across the spectrum of conflict from seabed to space and sea to land (FORCEnet, 2007a). FORCEnet is, thus, the future implementation of the Network Centric Warfare in the Navy, and is the Navy's primary effort to integrate multiple architecture and standards efforts. Research efforts demonstrated that across the Navy Enterprise, FORCEnet viability, affordability and sustenance necessitates an architecture that is in full compliance with OA technology, systems and standards. The development and embedding of OA within FORCEnet will enable a superior, adaptive, "plug and fight" capability for the modern warfighter of today and tomorrow. Figure 2 presents the system interface view of FORCEnet.

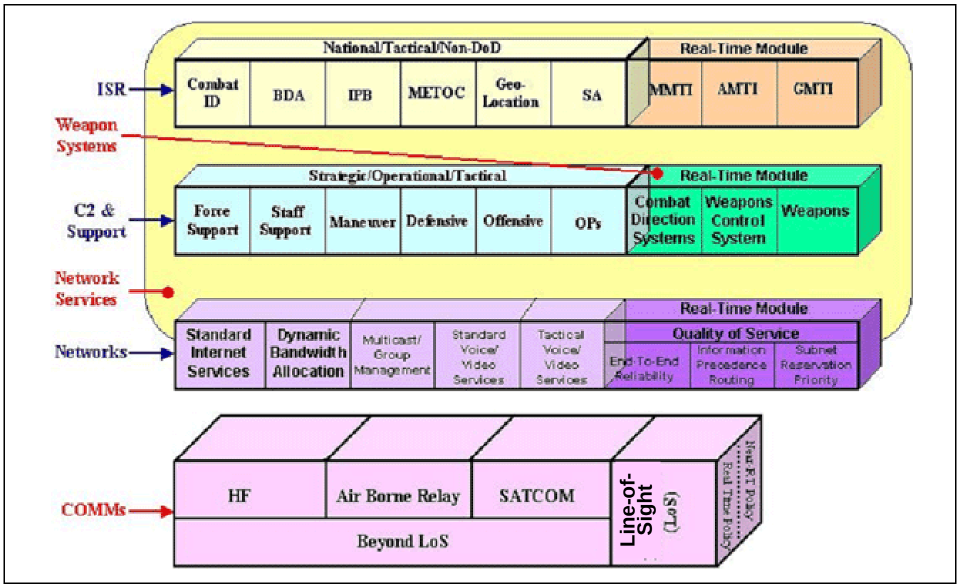

Figure 2. FORCEnet's System Interface Description
(extracted from FORCEnet, 2007b)

The Naval Open Architecture Enterprise Team (OAET) is currently spearheading an OA/FORCEnet Risk Reduction Experimentation effort to minimize the risk of delivering interoperable products (Shannon, 2006). This effort is in its early stages and has recently completed its first cycle. An example of a project enabling the integration of OA into FORCEnet is the “Open Architecture as an Enabler for FORCEnet” project (Deering et al., 2006, September). It concentrates on implementing network-centric military operations with specific threat-engagement scenarios (i.e., sensed threats to available weapons). These concepts are applied to the FORCEnet OA Domain Model using legacy and future warfare/Navy systems based on OA concepts. An analysis exposed potential functional boundary limitations in the current OA Domain model, and a revised model has been proposed.

The Modular Open Systems Approach (MOSA) (Open Systems Joint Task Force, 2007) is both a business and technical strategy for developing new systems or modernizing existing ones (see Figure 3).

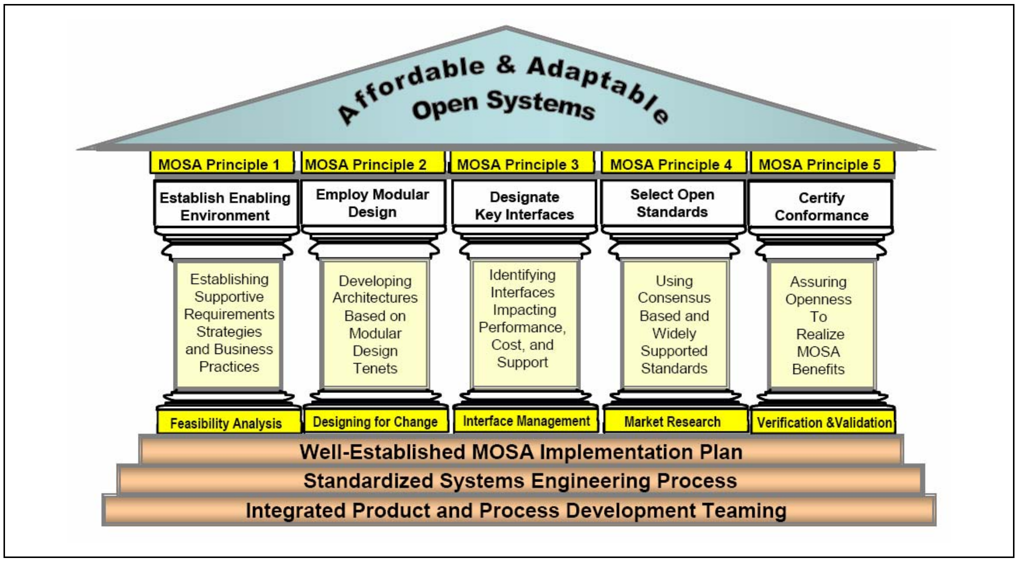

Figure 3. MOSA's Fundamental Building Blocks
(extracted from Flowers & Azani, 2004)

As a business strategy, the MOSA enables program teams to build, upgrade and support systems more quickly and affordably. This can be achieved through the use of commercial products from multiple sources and by leveraging the commercial-sector investment in new technology and products. The technical portion of the MOSA addresses a system design that is modular, has well-defined interfaces, is designed for change and, to the extent possible, makes use of commonly used industry standards for key interfaces. This system design is best accomplished using collaborative engineering based on sound systems engineering processes. Adherence to MOSA allows for developing DoD systems that account for the growing asymmetrical threats, unprecedented rate of technological change, and requirements for joint warfighting capabilities. The Navy's OA is closely related to MOSA. OA is a more specific extension of generalized MOSA principles. Naval OA applies to computer-intensive National Security Systems as defined in the Clinger Cohen Act, while MOSA has broader applicability, e.g., including mechanical systems.

The successful implementation of OA principles in the Navy may bring multiple benefits from both business and technical viewpoints to the Navy and other DoN/DoD organizations. Business benefits include: (i) enterprise-wide plans based on a cost/capability analysis of programs that address capability, affordability, and stabilization, (ii) flexible acquisition strategies and contracts that enable the Navy to reuse software, easily upgrade systems, and share data throughout the enterprise, (iii) streamlined investments in similar capabilities, (iv) increased competition to foster innovation and leverage technology upgrades, and (v) established enterprise processes and governance to foster integration. On the other hand, an efficient implementation of OA principles yields many technical benefits, including: (i) layered and modular open architectures that address portability, maintainability, interoperability, upgradeability and long-term supportability, (ii) modular, open designs consisting of components that are self-contained elements with well-defined interfaces, (iii) maximum use of commercial standards and commodity "commercial off-the-shelf" (COTS) products, and (iv) systems that continuously conform with Information Assurance (IA) requirements and monitor technology developments for IA improvements.

Figure 4 below presents a synthesis of OA benefits.

Performance	• Continuous competition yeilds best of breed applications • Focus on warfighting priorities
Schedule	• System integration of OA compliant software happens quickly • Rapid update deliveries driven by use operational cycles
Cost Avoidance Mechanisms	• Software - develop once, use often, upgrade as required • Hardware - Use high-volume COTS products at optimum price points • Training systems use same tactical applications and COTS hardware
Design for Maintenance Free Operating Periods	• Install adequate processing power to support "fail-over" without maintenance • Schedule replacement with improved COTS vice maintaining old hardware • Reduce maintenance training required • Consolidate Development and Operational Testing for reused applications
Risk Reduction	• Field new applications only when mature • Do not force the last ounce of performance • Deploy less (but still better than existing) performance or wait until next update

Figure 4. Open Architecture Benefits
(extracted from DAU, 2007C)

The Navy still needs to complete carrying out the necessary business and technical changes to achieve the stated OA goals. Well-known technical changes include the need for continuing the transition to COTS-based computing plants in modular architectures, the development of an OA Enterprise component library capability to facilitate market research and reuse of components, the alignment of standards among the domains and the alignment of standards to the DoD Information Technology Standards Registry (DISR). This paper identifies additional technical changes related to test and evaluation.

Difficulties in Testing Systems with Open Architectures

The Navy has emphasized improving its business and organizational processes, structure and expertise over technical matters. The Navy is currently able to deliver open architecture-based systems. However, known methods for achieving dependability with OA are expensive and not clearly understood. The Navy's current approach to system testing is not well matched to the needs of open environments. It is too expensive; it takes too long, and it lacks agility to react to changes during and after acquisition.

Traditional testing techniques, such as scenario-based testing, are commonly used for assessing dependability of Navy systems. These techniques are strongly dependent on a particular system configuration and environment. The environment is usually modeled using flat, uniform distributions of software inputs and a limited number of profiles. Accordingly, the environment's profile and the most relevant estimates of the application inputs are considered. For example, in Navy's control systems, input parameters such as the number of weapons or the number of strike elements are included within the testing profiles.

The drawback of these techniques is that when the system configuration or environment changes, the designed test cases also need to be changed. Plugging in a new component will lead to a completely different system and will likely invalidate the test scenarios and profiles previously used. A similar problem also occurs when the application has to be used in an operational environment other than the one for which it was originally designed, which is expected to be common for reusable components. This raises an

important concern since Navy systems are submitted to frequent changes. Better ways of doing testing and evaluation are, thus, highly desirable.

Acquisition of new system modules and components is also an important concern. While an architectural or modular approach should allow for a certain degree of predictability, current Navy testing processes do not deal with modularity. As a result, time-consuming and expensive test procedures are needed each time a new system release comes up because available testing methods cannot support the high frequency of releases. Methods that limit the number of configurations of an architecture might be required, at least in the near term. Such limitations may be able to be relaxed as technologies for testing families of systems improve.

In flexible, open systems, components need to be assembled in a large number of configurations; and because the system is open, new components can be added that did not even exist at the time the system was originally designed.

In practice, the number of possible configurations for an open system is very large, because each of many slots in an open architecture can be independently filled by several different specific subsystems. Because the number of choices for each slot must be multiplied together to produce the total number of possible configurations, the number of possibilities is astronomical for the kinds of systems designed by the Navy. For example, it has been estimated that avionics software systems have thousands of components and tens of thousands of connections. In principle, the number of configurations is unbounded because an unknown and unlimited number of new subsystems can be created in the future. One consequence of this is that it will be impossible to test all configurations, and that a majority of the possible configurations will not be tested at all. These ideas are graphically summarized in Figure 5.

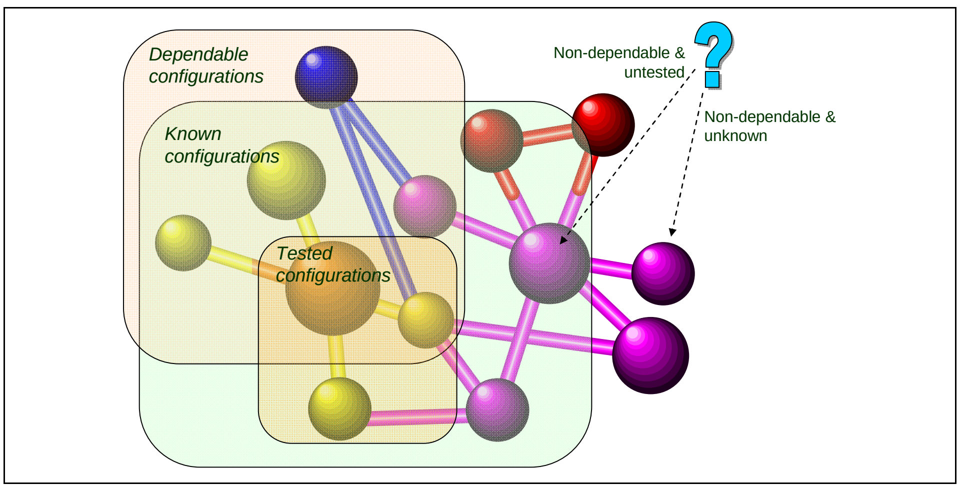

Figure 5. Example of Various Sets of Configuration Types: Dependable vs. Non-dependable, Known vs. Unknown, Tested vs. Untested

Each node in the figure represents a possible configuration of an open architecture. The connections between the nodes represent transitions between possible configurations, such as those resulting from the replacement of a subsystem with another plug-compatible subsystem that fits in the same slot of the open architecture. The figure is valid at many different scales; a module can be as small as a single data item, software procedure, or integrated circuit chip, and can include subsystems as large as entire ships. Figure 5 also highlights two important concerns (indicated by the interrogation point): the non-dependable

configurations that are unknown and the non-dependable configurations that (although known) have not been tested. Indeed, the number of configurations in practice is too large to be able to either know or test all of them. We seek alternative methods to palliate these issues.

These considerations indicate that quality assurance methods that depend on checking the individual possible behaviors of the entire system do not have any hope of being effective for the test and evaluation of flexible open architectures, and that conceptually new and different methods will have to be employed to achieve dependability for such systems in the presence of reuse and reconfiguration.

Testing of reusable subsystems is also subject to the above considerations and, similarly, requires new methods for effectively achieving dependability. This conclusion is consistent with past experience with system failures in military, scientific and commercial applications. The majority of observed failures are due to requirements and specifications errors, many of which manifest after a subsystem has been moved to a different environment than the one for which it was originally designed and tested. This is an indication that in current practice, the effectiveness of testing is very sensitive to the expected operating environment, which is unknown for reusable subsystems. Indeed, software reuse may invalidate the operational profiles and test cases and scenarios originally developed. The new operational profiles, test cases and scenarios are unknown, and no efficient method exists to calculate the required “delta” describing the necessary changes from previously used profiles (or test cases or scenarios) so that they can be applied to the newly reconfigured system. Open Architecture facilitates software reuse, which adds weight to this issue.

Test cases correspond to the traditional artifact used in testing, which are based on a model of the system environment. In stovepipe systems, requirements analysis and testing is greatly simplified compared to open systems. Also, there exist numerous methods and techniques that allow for linking the testing results to dependability parameters, so as to obtain a quantitative measure of the overall dependability of the system (e.g., notion of “dependability benchmarking”).

The traditional concept of system design is not focused on architectural “bits.” An architecture is related to a family of systems, while a design is traditionally associated with a single instance of a system. Also, an architecture involves more complexity than the traditional notion of system “configuration.” This is due to the fact that the “context” is included in the architecture, which is usually unknown, not well understood or difficult to accurately take into account.

The type of dependability properties to be tested is also an important concern. Making Navy systems dependable will require considering a certain level of system performance and availability as part of the dependability concern. Indeed, architectural changes can considerably impact Key Performance Parameters (KPP), availability and other system requirements. Other concerns relate to how testing can be applied to Navy systems that are based on migrating services (e.g., reconfiguration of service-based architectures) and how system developers and testers can be involved in the acquisition process. At the moment, it is not possible to accurately know how much it may cost to move towards an open architecture paradigm.

Proposed Approach

In the short term, the problems outlined in the previous section are being addressed by attempting to predict future needs and by limiting the allowed configurations accordingly. This has the advantage of minimizing impact on current development processes and organizations, and the disadvantages that cost of testing is sill large and proportional to the number of reconfigurations, and that in cases in which predictions of future needs turn out to be incorrect, reconfigurations will need time for lengthy retesting, or new configurations will have to be fielded without assurance of dependability. However, in the Navy's Open Architecture vision, the "plug and fight" process is supposed to be inexpensive and agile.

The main objective of the OA approach is to get away from monolithic designs and architectures, and gain the ability to replace bits of systems. The goal is to facilitate DoD/Navy systems acquisition. This requires a shift from scenario-based testing to architecture-based testing. The constraints expressing the most important dependability properties should be part of the architecture. The architecture should, thus, include not only components and connections but also constraints. Note that there are different types of constraints—encompassing requirements, capabilities and standards (capabilities are similar to requirements). A dependable architecture should have requirements associated with it, which means that certain dependability guarantees should be already reflected in the architecture itself. Then, testing is not only to be applied to the system implementation, but also to the architectural model.

Thus, fully realizing the open architecture vision requires a new paradigm for test and evaluation. We propose such a paradigm here, based on the concepts of dependability contracts, interchangeable software parts, and computer-aided enforcement of dependability contracts.

Current approaches to system development and testing are more analogous to individual craftsmanship than they are to modern concepts of mass production and interchangeable parts. Craftsmen used to build things by individually tuning mating parts until they properly fit together. In such a context, designs could be relatively informal and relatively rough. In a mass production environment, parts are built to standards with precisely specified tolerances, and it is up to the designer to determine and verify the tolerances necessary to make the design work for any combination of parts that meet the specified tolerances. An example that illustrates this problem is the manufacturing of a rifle using a set of interchangeable parts. This is different from having parts that need to be crafted individually. It is necessary to evaluate how much variation is allowed to make different components and parts fit into the rifle. To do this, it is necessary to measure absolute sizes and construct the various parts of the rifle with certain tolerances. These modular approaches have been used in manufacturing for many years, but have never been successfully integrated into software engineering approaches. Another example consists of modern audio systems. There exist specific standards for audio systems specifying how things need to fit together in order for components from different vendors to work together effectively. Standards for audio system components can be relatively simple and generic only because the requirements for stereo systems are very simple. An audio system is not concerned about whether it is playing a song or the news. For systems whose behavior is sensitive to the meaning of the data, new types of standards will be needed to accomplish a similar function. These examples raise questions related to the kinds of standards that need be considered to make system components interchangeable and how such changes may influence testing. The answers to these questions should take into account the fact that we

aim at testing pieces of the architecture versus standards, not versus (other pieces of) the system.

We are seeking analogous quality-assurance techniques for systems involving software. The fundamental operation of such an approach can be outlined as follows:

1. System-wide capabilities are characterized by a set of dependability properties that must hold in all acceptable system configurations. These properties comprise the dependability contract for the system as a whole. They become part of a dependable open architecture for the system and serve as the basis for system quality assurance. Dependability contracts are primarily technical rather than legal documents, and they are intended to be checkable via software.

2. The designers of the open architecture determine the common structure of the system and develop the component-level dependability contracts for the subsystems and connectors. The common structure consists of connection patterns and subsystem slots to which all configurations must conform.

3. The quality-assurance team checks the structure of the architecture and the dependability contracts for subsystems and connectors to make sure they are strong enough to guarantee the system-wide dependability properties in all possible configurations. This is a one-time process that uses symbolic analysis techniques. Assuring the feasibility of this step is one of the objectives of ongoing research by the authors.

4. The quality assurance team tests each component (subsystem and connector) against its dependability contract. This is envisioned to be an automated process to enable sufficient large sets of test cases for statistically significant conclusions about desirable dependability levels. The cost for this step is proportional to the number of components, and the process must be completed once for each version of each atomic component. Technologies for doing this are well known, and many of them are used in common practice.

5. The quality-assurance team checks components for non-interference. This process is computer-aided. Many of the technologies for this are well known, and some of them are commonly used. Some development may be needed to get a complete set. This part of the process ensures that components that work correctly in isolation will continue to do so when they are connected.

6. The assumptions about the operating environment on which the architecture depends are checked by runtime monitoring. This can be done using BIT (Built-In-Test) technology that is currently in use in some DoD systems. This is recommended for all reusable components.

Figure 6 provides an overview of the global approach. The architectural and testing visions of the proposed approach are described below:

- Architectural vision
    - Consider an architecture as a support system not only for development but also for testing—including interchangeable software parts.

- Look at an architecture as consisting not only of components, connections and constraints, but also of standards, requirements/capabilities and environmental assumptions.

- Testing vision
    - Relate testing to standards and constraints as a means to ensure architecture meets requirements and provides the needed capabilities.
    - Relate standards to architectural structures and associated dependability requirements.
    - Certify absence of interference between components and the dependability properties of interest.
    - Check constraints on environment at reconfiguration time.
    - The purpose is to prevent problems (such as integration problems). When feasible, this is better than detecting those problems. The approach should allow for making responsibilities more visible.

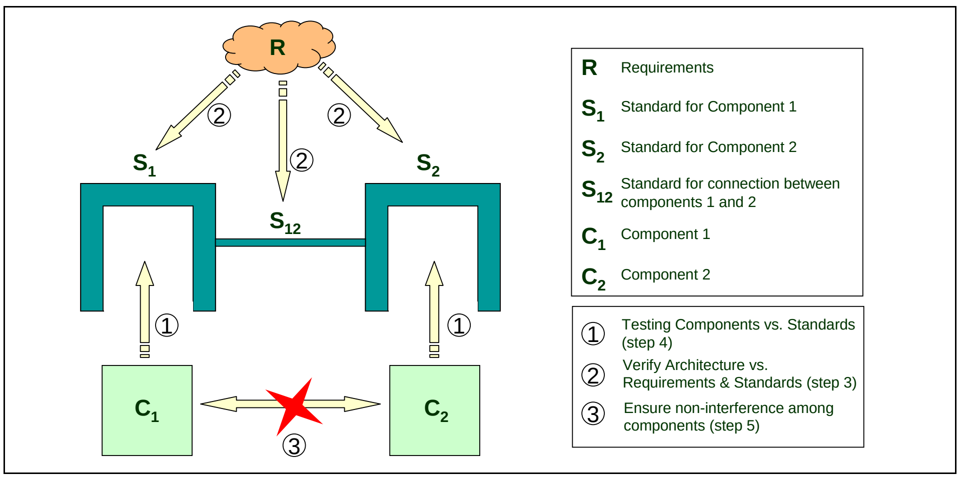

Figure 6. Overview of the Global Approach

The above process is a long-term goal whose realization depends on refinement and integration of new technologies and processes—especially those supporting steps 3 and 5.

Full success of the approach will eliminate the need for integration testing after each reconfiguration. This is the meaning of interchangeable software components. We do not propose to eliminate integration testing entirely, even in the long term. The reason is that all analysis is relative to a model. While the models we use are good, it is always possible that the existing implementation does not realize the intended model completely precisely. For example, it is possible that the compiler used does not implement its programming language correctly in some rare cases, or that the hardware does not perform its functions as specified under some rare conditions. For these reasons, we recommend integration testing for at least one system configuration, e.g., the initial configuration to be fielded. Shorter-term reductions in the amount of testing needed after a reconfiguration are expected when effective non-interference checks eliminate specific kinds of failures due to integration issues.

Some examples include interference due to data or control interactions that are not allowed by the architecture, or due to resource constraints such as limits on memory, network bandwidth, or computation time. An example of existing technology that can eliminate a specific type of interference is architecture-based schedulability analysis, which can guarantee absence of failures due to real-time constraints and computing resource limits.

Another related issue is how to certify a standard. The certification method should be able to satisfy the critical requirements of all architectural configurations. Quality assurance and analysis techniques (such as model checking or theorem proving) could be used for such purposes. These techniques are well-known, well-established and have been used for many years. However, these techniques do not scale-up well. The reason is that they have traditionally been applied to program code, which is a very large artifact. We believe this technology can be applied to the architecture of a system because the architecture is much smaller than the code. This is especially the case if each level of the architectural hierarchy can be checked separately. To make this possible, the traditional concept of architecture should be enhanced, e.g., constraints and standards should also be included.

Another issue is that to check the absence of interference between components, static-analysis techniques (e.g., type checking, static checking, code analysis) will be needed, since testing is not enough for this purpose. This means that reachability analysis techniques will necessarily be different. The underlying approach might be “large scale.” but it does not mean it needs to be sophisticated (just feasible). Moreover, if testing is conducted against a standard, it is possible to have an automated testing oracle. In classical reliability techniques, it is possible to calculate the number of test cases needed to assure (with a certain confidence level) that the system will not experience more than a given number of failures during a determined period of time. For example, if the system should not fail more than once in N executions, the number of test cases needed for a confidence level of 1-1/N is given by Nlog2 N. (e.g., about 20 million test cases are needed to reach 10EXP-6 assurance).

Testing with respect to standards can drastically reduce the number of test cases needed because each component can be tested separately, and all possible combinations do not need to be checked. However, this source of potential savings depends on effective methods for carrying out steps 3 and 5 above.

Some shorter-term savings can be achieved by using testing approaches that obtain information about many different configurations based on a single test case run on a single configuration. An example is an approach that tests every pair of components that are connected in the architecture in at least one system configuration, but not in all possible contexts.

The major contributions and advantages of the proposed approach are:

- *Ability to reduce the testing effort*. The approach will enable reducing unnecessary testing on every system change and enable identifying what kinds of testing and checking do need to be repeated when something changes.
- *Ability to limit the retesting scope*. The approach will limit the scope of retesting when possible. This will involve a combination of testing with other kind of quality-assurance techniques.

- *Ability to assure dependability*. The approach will include methods for assuring, with a single analysis, that all possible configurations that can be generated in a model-driven architecture will satisfy given dependability requirements. Prior successful experience with developing methods of this kind has been demonstrated by the first author of this paper (Berzins, 2000). These results will be extended and applied to fit the requirements of the Navy open-architecture initiative.

Example

A simple example of part of a dependable architecture is shown in Figure 7. There are two component slots, one representing the software driver for a position sensor, and the other a control software module for an autopilot. There is one connector that carries information about the current position of the host platform. The example shows just a fragment of a realistic architecture as indicated by the ellipsis on the connections. In a complete architecture, the position information will also feed into other systems, such as tactical displays and weapons control systems.

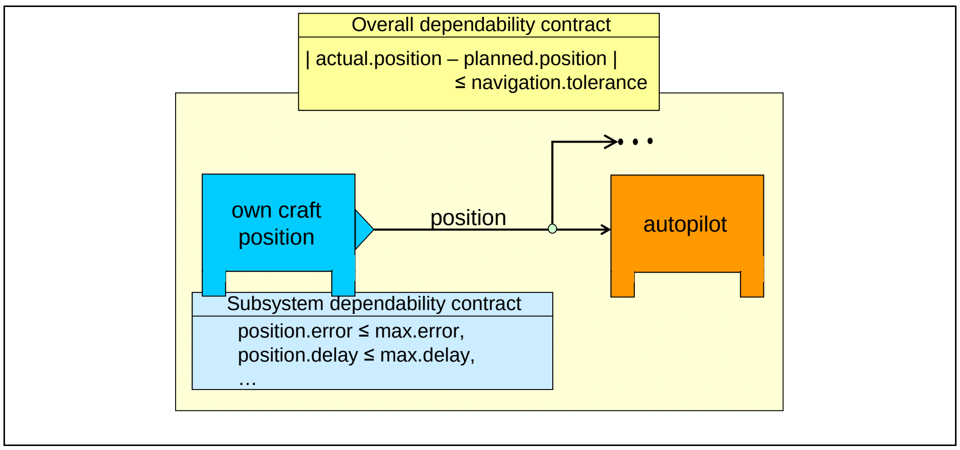

Figure 7. Example of a Dependable Architecture Fragment

The figure shows a simplified[40] partial description of the dependability contracts. The overall purpose of the interconnection is to keep the platform on course. This informal intent is expressed as a measurable dependability property that becomes the basis for the quality assurance of this architectural fragment. The navigation tolerance is a parameter of the overall system requirements as well as of the architecture. It provides a partial characterization of mission needs and a family of system configurations that meet that need. For example, different types of platforms may have different navigation tolerances. Note that this same architecture fragment is relevant to surface, subsurface and air platforms. The own-craft-position subsystem slot can be filled by a variety of sensors, such as GPS, inertial, VOR/DME, etc., and the autopilot subsystem slot can likewise be filled with components that realize different control algorithms. The subsystem dependability contract expresses part of the standards that any acceptable realization of the subsystem must meet—by expressing tolerances—for the accuracy of the sensor and the allowable time delay between the time the platform's position is measured and the time the position is delivered to the connector. It is the responsibility of the designers of the architecture to determine how the values of these

[40] For example, for air platforms, the vertical navigation tolerance can be different than the horizontal tolerance.

subsystem dependability parameters are derived from the overall dependability parameter. The purpose of Step 3 in the proposed quality assurance process is to check that this derivation is valid in the sense that the system will meet its requirements for any choice of sensors that meets its dependability contract, as well as for any choice of control algorithm that meets its dependability contract (not shown). This process depends on mathematical modeling, analysis and proof techniques, some existing and some to be developed.

The process of reconfiguring the system fragment in the example would amount to replacing the sensor and its software driver with another one. The quality-assurance activities associated with this would be certifying that the new component meets the dependability properties in the own-craft-position dependability contract (Step 4) and non-interference checks between the new component and the other components in the new configuration (Step 5).

Our objective is to provide static analysis methods to accomplish Step 5. If a complete set of such methods can be provided, then integration testing will not be needed after such a component replacement. If some but not all of the potential interference modes can be ruled out by static checking, then some integration testing will still have to be performed as part of Step 5, but the scope of that testing can be focused on the failure modes that are not yet covered by static checks. We note that although we have been mostly focused on replacement of software components, sometimes, as in this example, a meaningful reconfiguration may involve replacement of some hardware as well. In our example, some kinds of improvements may be possible by replacing just the driver software for a given sensor, but the largest gains may come from combining a new and more accurate type of position sensor with the new software driver needed to make the new sensor fit the existing subsystem slot in the architecture. The goal is not to change the architecture when the system is reconfigured. In such cases, the non-interference tests may include electrical, thermal and mechanical considerations in addition to software consideration.

Our recommendation is to identify potential sources of interference in detail, and to develop specific quality-assurance techniques for assuring absence of each type. These can involve a combination of static analysis checks, such as: data-type consistency, lack of unspecified data flow, lack of unspecified control flow, conformance to power and heat load limits, etc., with conventional testing processes. We also note that in some specific contexts, specialized efficient testing procedures are possible, for example, where dominance relations exist. For instance, in continuous domains it is common that a single worst-case test case can expose all the faults that any other test case could detect.

The dependability contracts in the example also have a dominance property: if a component has been certified with respect to a component with a larger error tolerance, it will also work for one with a smaller error tolerance, because every possible behavior of the more accurate component is also a possible behavior of the original, less accurate component. In the example, a sensor with a given max.error and max.delay can be replaced with any other sensor that has a smaller max.error and smaller max.delay provided that the new sensor also passes all non-interference checks.

We note that a kit of available components can be pre-certified with respect to Steps 4 and 5. This would enable agile dependable reconfiguration, and perhaps even a capability for on-the-fly "plug and fight." The cost to do Step 4 is proportional to the number of components, and can economically be completed in advance. The cost to do Step 5

depends on whether generic non-interference methods can be developed for all needed failure modes. In the best case, it is proportional to the number of components and could be done in advance. If all-pairs analysis is necessary, cost would be quadratic in the number of components—making pre-checking expensive but still perhaps feasible in advance if the number of components in the reconfigurable part is not too big. In the worst case, where multiple interactions may be significant, some non-interference checking may still be required after reconfiguration, when the actual set of components in the new configuration is known.

Comparison with Related Work

The purpose of this section is to provide a comprehensive survey on existing approaches for improving Quality Assurance properties of open and flexible architecture-based systems. It is also an objective to review existing works on how testing is performed in a fluid environment with agile reconfiguration.

Comparison with Navy's Approaches

The Naval OA program interacts with the OACE, FORCEnet and MOSA initiatives in different ways. As described above, OACE is based on a set of standards for the computing environment of surface ship-centric systems specifications; MOSA is an acquisition and design approach, while FORCEnet is a unifying concept for multiple architectures and standards efforts in the Navy. The recommended testing practices are described by these standards in general terms and are mostly founded on scenario-based techniques. For example, OACE recommends functional and performance testing against specified system requirements, organized according to test cases and scenarios. It defines the concept of "virtual homogeneity" to facilitate testing by identifying groups of sub-systems performing similarly. The concepts of "tree of subsystems" and "aggregations of components" are also introduced. Each aggregation exists only in a manageable number of configurations. A test case can be applied to many configurations when there is no (considerable) interaction between choices of configurations. Schedulability analysis is recommended for ensuring that any configuration that the resource manager creates is schedulable. These are existing attempts to reduce cost of testing by limiting flexibility of systems and to increase confidence that a test case provides useful information about more than one configuration by limiting possible sources of interference between components.

Our methodology aims at defining a broader testing approach covering both functional and non-functional properties of Open Architecture-based systems, with emphasis on ensuring dependability for all possible system configurations. Instead of seeking for subsystems performing similarly (concept of "virtual homogeneity"), our approach will use architectural artifacts and standards which already define the basis for all the different groups of subsystems that can be developed in practice. In our context, "performing similarly" means "meeting the dependability contract associated with a subsystem slot in the open architecture." Since our approach will work at the architectural level, and the architecture represents a family of systems and subsystems, the concepts of "tree of subsystems" and "aggregation of components" will be also covered. The non-interaction between choices of configurations is already covered by the concept of non-interference defined in our approach. Schedulability analysis is also part of the non-interference notion, since it will allow for predicting resource conflicts between tasks and processes.

Comparison with Component-based Testing

Component-based testing can be readily employed for Step 4 of our methodology to further test a candidate software component against the specific domain and architectural standards of the target system in which it is to be plugged-in and integrated.

Traditionally, component-based testing is performed by the component's developer itself (e.g., through unit testing). It is aimed at establishing the proper functioning of the component and at detecting possible failures early, i.e., ensuring the quality of the component before it is released. The tests established by the developer can rely not only on a complete documentation and knowledge of the component, but also on the availability of the source code, and, thus, in general pursue some kind of coverage testing. Therefore, when applied by the component's developer, this testing approach cannot address the verification of the component's behavior with respect to the specifications of the host system(s) in which the component will be later assembled (i.e., integration and system testing). Note, however, that component-based testing techniques are also used by system testers and integrators.

Voas (1998, June; 2000, August) proposed a certification strategy for off-the-shelf components relying on black-box testing, system-level fault injection and defense protection through wrapping. Black-box testing is a well-known testing technique used whenever the source code of a component is not available, only its interface specifications. System fault injection and defense wrapping are system-level approaches for integration testing and fault containment that might not be needed in our approach if the non-interference property is fully satisfied.

Other approaches aim at making component's data available (e.g., internal behavioral and structural data, development data, etc.) so that the data can assist the testing process. The work in Orso, Harrold and Rosenblum (2001) defines an approach in which metadata of a component (describing both static and dynamic aspects) are available throughout the entire component's lifecycle. The feasibility of the approach is demonstrated in the context of component-based testing, consisting of the generation of self-checking code and program slicing. The work in Whaley, Martin and Lam (2002) automatically extracts a finite-state machine model from the interface of a software component, which can be delivered along with the component itself for testing purposes. Off-the-shelf (OTS) components are usually acquired as black-box code without access to data that might be necessary for testing. Salles, Rodriguez, Fabre and Arlat (1999) developed a framework for integration testing of OTS real-time operating systems (RTOS). Information needed for testing is obtained through reflective techniques implemented in an additional software module added to the OTS component. A fault-injection methodology is used to verify that the behavior of the integrated OTS component does not impact the dependability of the system.

Bertolino and Polini (2003) recognized the importance of testing a software component in its deployment environment (i.e., the target system). They developed a framework that supports functional testing of a software component with respect to customer's specification—which also provides a simple way to enclose the developer's test suites which can be re-executed by the customer. The customer is thus provided with both a technique to specify a deployment test suite early and an environment for running and reusing the specified tests on any component implementation. There is a complete decoupling between the tests' specification and component implementation. The approach

requires the customer to have a complete specification of the component to be incorporated into a system.

In the formal verification domain, there has been a long history of research on verification of systems with modular structure. A key idea (Lamport, 1983; Kupferman & Vardi, 1997; Henzinger, Qadeer & Rajamani, 1998) in modular verification is the assume-guarantee paradigm: a module should guarantee to have the desired behavior once the environment with which the module is interacting has the assumed behavior. There have been a variety of implementations for this idea (see, e.g., Grumberg & Long, 1994; Alur et al., 1998; Pasareanu, Dwyer & Huth, 1999; Dingel, 2003; Chaki, Clarke, Groce, Jha & Veith, 2003; Xie & Browne, 2003). The key issue with the assume-guarantee style reasoning is how to obtain assumptions about the environment. Giannakopoulou et al. (Giannakopoulou, Pasareanu & Barringer, 2002; Giannakopoulou, Pasareanu & Cobleigh, 2004) introduced a novel approach to generate assumptions that characterize exactly the environment in which a component satisfies its property. Their idea is based on a purely formal verification technique (model-checking). Fisler et al. (Fisler & Krishnamurthi, 2001; Li, Krishnamurthi & Fisler, 2002) introduced a similar idea of deducing a model-checking condition for extension features from the base feature for model-checking, feature-oriented software designs. This approach is not applicable to component-based systems where unspecified components exist. This work differs from related work like Xie and Dang (2004), in which an automata-theoretic approach is used to solve a similar LTL model-checking problem.

In the past decade, there has also been significant research on combining model-checking and testing techniques for system verification, which can be grouped into a broader class of techniques called specification-based testing. Many of the studies utilize model-checkers' ability of generating counter-examples from a system's specification to produce test cases against an implementation (Callahan, Schneider & Easterbrook, 1996; Holzmann, 1997, May; Engels, Feijs & Mauw, 1997; Gargantini & Heitmeyer, 1999; Ammann, Black, & Majurski, 1998; Black, Okun, & Yesha, 2000). Peled et. al. (Peled, Vardi & Yannakakis 1999: Groce, Peled & Yannakakis, 2002; Peled, 2003) studied the issue of checking a black-box against a temporal property (called black-box checking). The research focuses on how to efficiently establish abstract models for black-box testing and on how to define properties (e.g., LTL formula) about the black-box components.

Comparison with Runtime Software Reconfiguration

For an important class of safety- and mission-critical software systems, such as air traffic control, telephone switching, and high-availability public information systems, shutting down and restarting the system for upgrades incurs unacceptable delays, increased cost, and risk. Support for runtime modification is a key aspect of these systems. In our methodology, a reconfigured set of components can be seen as a particular configuration of a system architecture. Since our approach aims at guaranteeing dependability properties for the family of systems and configurations represented by the architecture, the proposed testing approach should be able to provide assurance in presence of runtime reconfiguration for at least a certain number of properties (e.g., non-interference).

There are a wide variety of techniques for supporting runtime software change. Some of the most popular techniques are based on Dynamic Software Architectures (Oreizy, 2007). Several research projects have addressed these issues, such as Self-Adaptive, Healing Architectures (ArchShell, 2007), or Dynamic Wright (Allen, Douence & Garlan, 1998, April). Gupta, Jalote and Barua (1996, February) describe an approach to

modeling changes at the statement and procedure levels for a simple imperative programming language. Many dynamic programming languages, such as Lisp, Smalltalk, and Haskel (Peterson, Hudak & Ling, 1997, July) have supported runtime software change for decades. Dynamic linking mechanisms and libraries have been available in operating systems such as UNIX, Microsoft Windows, and the Apple Macintosh for some time. New approaches to dynamic linking (Franz, 1997, March) hope to significantly reduce the runtime performance overhead associated with using such mechanisms. Dynamic Object Technology, such as CORBA (Object Management Group, 1996, July) and COM (Brockschmidt, 1994) support the runtime locations, loading, and binding of software objects or components.

Service-oriented architectures (SOAs) typically have a dynamic nature, given by the runtime detection of components through registry services and subsequent dynamic binding. The work in Baresi, Heckel, Thone, and Varro (2006) defines a refinement relation from a generic style of component-based systems to the SOA style based on the use of graph transformation systems as models of architectural styles at different levels of platform abstraction (which represent reconfiguration and communication scenarios as graph transformation sequences). Besides the many proposals for Architecture Description Languages (ADLs), like Rapide (Luckham et al., 1995; Oreizy, 1996, August; Oreizy, Medvidovic & Taylor, 1998, April), Wright (Allen, 1997; Allen, Douence & Garlan, 1997, September; Allen, Douence & Garlan, 1998, April; Allen, Douence & Garlan, 1998), Darwin (Magee, Dulay, Eisenbach & Kramer, 1995; Kramer & Magee, 1998) or C2 (Medvidovic, 1996, October; Oreizy, Medvidovic & Taylor, 1998, April), we must mention those approaches that exploit graph transformation (Hirsh, 2003; Hirsh & Montanari, 2001, August; Metayer, 1996, October; Taentzer, Goedicke & Meyer, 2000; Wermelinger & Fiadeiro, 2002; Baresi, Heckel, Thone, & Varro, 2003; Gonczy, 2006) to reason about the consistency of reconfiguration operations and interaction of components with respect to structural constraints. Le Metayer (1996, October) describes architectures by graphs and the valid graphs of an architectural style by a graph grammar. Reconfiguration is described by conditional graph-rewriting rules. He uses static-type checking to prove that the rewriting rules are consistent with the respective style. The graphs represent computational entities but not connectors, specifications, or other resources. Wermelinger and Fiadeiro (2002) provide an algebraic framework based on Category theory in which architectures are represented as graphs of CommUnity programs and superpositions. Dynamic reconfigurations are specified by graph transformation rules over architecture instances. Both styles and rules are used for modeling domain-specific restrictions rather than the underlying platform. Consequently, they do not deal with refinement relationships between different levels of platform abstraction. Hirsch (2003) uses hypergraphs to represent architectures and hyperedge replacement grammars to define the valid architectures of an architectural style. Furthermore, he uses graph transformation rules to specify runtime interactions among components, reconfigurations, and mobility. In the CHAM approach (Inverardi & Wolf, 1995, April), architectural reconfiguration is studied in terms of molecules and reactions, and the proposals that represent architectural styles by means of graph grammars (Hirsh & Montanari, 2001, August; Metayer, 1996, October; Taentzer, Goedicke & Meyer, 2000; Wermelinger & Fiadeiro, 2000, March) and reason on changes and evolution with respect to structural constraints. Some of these approaches use a graph grammar to specify the class of admissible configurations of the style. Graph transformation rules model only dynamic aspects like evolution and reconfiguration. The advantage is that a declarative specification is more abstract and easier to understand, even if constructive/operational ones are better for analysis and tools. The use of graph-transformation techniques to capture dynamic semantics of models has also been inspired by work proposed by Engels,

Hausmann, Heckel and St. Sauer (2000) under the name of dynamic meta-modeling. That approach extends metamodels—re-defining the abstract syntax of a modeling language like UML by using graph-transformation rules that allow for describing changes to object graphs and represent the states of a model.

Grammar-oriented Programming (GOP) and Grammar-oriented Object Design (GOOD) (GOOD, 2002) are based on designing and creating a domain-specific programming language (DSL) for a specific business domain. GOOD can be used to drive the execution of the application, or it can be used to embed the declarative processing logic of a context-aware component (CAC) or context-aware service (CAS) (Arsanjani, Curbera, & Mukhi, 2004). GOOD is a method for creating and maintaining dynamically reconfigurable software architectures driven by business-process architectures. The business compiler was used to capture business processes within real-time workshops for various lines of business and create an executable simulation of the processes used. Instead of using one DSL for the entire programming activity, GOOD suggests the combination of defining domain-specific behavioral semantics in conjunction with the use of more traditional, general purpose programming languages.

The use of model-checking techniques for verifying software architectures has been thoroughly studied. For example, vUML (Lilius & Paltor, 1999, October), veriUML (Compton, Gurevich, Huggins & Shen, 2000), JACK (Gnesi, Latella & Massink, 1999), and HUGO (Schafer, Knapp & Merz, 2001) support the validation of distributed systems (where each statechart describes a component), but do not support complex communication paradigms. These works study static systems whose topology cannot vary at runtime. Similarly, Garlan Khersonsky and Kim (2003, May) and the researchers involved in the Cadena project (Hatcliff, Deng, Dwyer, Jung & Ranganath, 2003, May) applied model-checking techniques to analyze specific architectures with a fixed topology based on the publish/subscribe paradigm. A formal approach that considers refinement of dynamic reconfiguration can be found in Bolusset and Oquendo (2002). The approach is targeted on the translation from one ADL to another rather than on the refinement between architectural styles. Cherchago and Heckel (2004) describe the application of graph transformations in the runtime matching of behavioral Web service specifications. In Heckel and Mariani (2005), the conformance testing of Web services is based on graph transformations, focusing on the automated test-case generation. The work of Bertolino and Polini (2006) utilizes the benefits of these approaches and defines fault-tolerant algorithms incorporated into appropriate reconfiguration mechanisms for modeling reliable message delivery by graph-transformation rules in SOA. Graph transformation is used as a specification technique for dynamic architectural reconfigurations in Wermelinger and Fiadeiro (2002), using the algebraic framework CommUnity. Hirsch uses graph transformations over hypergraphs (2003) to specify runtime interactions among components, reconfigurations, and mobility in a given architectural style. A profile for reliability was designed for J2EE applications in Rodrigues, Roberts, Emmerich and Skene (2004). In Zheng, Jun and Yan (2005), a pattern-based specification and runtime validation approach is presented for interaction properties of web services using a semantic web rule language (SWRL). GROOVE (Graphs for Object-oriented Verification, 2007) is a project centered around the use of simple graphs for modeling the design-time, compile-time, and runtime structure of object-oriented systems; it also focuses on graph transformations as a basis for model transformation and operational semantics. This entails a formal foundation for model transformation and dynamic semantics, and the ability to verify model transformation and dynamic semantics through an (automatic) analysis of the resulting graph transformation systems—for instance using model checking.

The techniques described above such as model checking and graph transformations can benefit several steps of our methodology. In Step 2 these techniques can be used to derive dependability contracts addressing reconfiguration, topology and connections properties and constraints at the system and subsystem levels. In Steps 3 and 4, these techniques can be used in combination with other symbolic analysis techniques and testing techniques for verifying the structure of the architecture and the dependability contracts. These techniques can also provide useful information about the various sources of interference between the target components and the host system, and can help determine suitable and alternate approaches to avoid those interference sources.

However, designers have traditionally sought alternatives to runtime change, especially for safety-critical applications such as combat systems. Several reasons account for this:

1. *It is usually avoidable*. Runtime change is not a critical aspect of many software systems, and several techniques have been devised to circumvent the need for runtime change altogether. Regularly scheduled downtimes, functional redundancy or clustering, and manual overrides are all examples of such techniques.
2. *It increases risk*. System integrity, reliability, and robustness are more difficult to ensure in light of runtime change.
3. *It increases cost*. There is typically a marked performance overhead associated with supporting runtime change. Additionally, few techniques have limited expertise; and a lack of proven techniques for supporting runtime change exasperates engineering costs.

Although “plug and fight” has been articulated as a goal, in the near term reconfiguration is likely to be more constrained and less agile due to weapons certification and doctrine issues.

Conclusion

This paper explores methods for test and evaluation of flexible systems with open architectures, and proposes an approach for substantially reducing the amount of testing necessary for dependable reconfigurable systems. The approach involves augmenting open architectures with measurable dependability properties associated with the system as a whole as well as dependability properties associated with slots for replaceable subsystems. It also involves augmenting testing with other kinds of quality-assurance methods. These additional methods include static checks for non-interference properties. The purpose of these checks is to ensure that components that work correctly in isolation will continue to do so in the context of a given dependable open architecture. In the long term, this approach should eliminate the need for integration testing after each reconfiguration, and in the short to medium term, it should substantially reduce the amount of integration testing required after reconfiguration.

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9 - Competitive Sourcing Savings: Reality or Illusion?

Wednesday, May 16, 2007 3:30 p.m. – 5:00 p.m.	**Panel 9 - Competitive Sourcing Savings: Reality or Illusion?**
	Chair: **Steve Kelman**, Professor of Public Management, John F. Kennedy School of Government, Harvard University, former Administrator, Office of Federal Procurement Policy **Discussant:** **Richard F. Sweeney**, Assistant Deputy Commandant, Installations and Logistics (Contracts and E-Business), USMC **Papers:** ***Monsters in the Closet: The Unanticipated and Uncontrollable Impact of Collective Bargaining Agreements in A-76 Sourcing Decisions*** **Lt. Col. Timothy S. Reed**, USAF, 325th Contracting Squadron, **Lt. Jenine Cowdrey**, USAF and **Capt. William Pike**, USAF Logistics Management Agency ***Does Competitive Sourcing Really Pay?*** **Allen Friar**, Defense Acquisition University

Chair: Steve Kelman, if Professor of Public Management, John F. Kennedy School of Government, Harvard University, former Administrator, Office of Federal Procurement Policy. A summa cum laude graduate of Harvard College, with a Ph.D. in government from Harvard University, he is the author of many books and articles on the policymaking process and on improving the management of government organizations. His new book, *Unleashing Change: A Study of Organizational Change in Government*, was published in June 2005 by the Brookings Instutition Press. His other books include a study on how to improve the government computer procurement process, entitled *Procurement and Public Management: The Fear of Discretion and the Quality of Government Performance* (AEI Press, 1990), and *Making Public Policy: A Hopeful View of American Government* (Basic Books, 1987). In l996 he was elected a Fellow of the National Academy of Public Administration. In 2001, he received the Herbert Roback Memorial Award, the highest achievement award of the National Contract Management Association. In 2003 he was elected as a Director of The Procurement Roundtable. He currently serves as editor of the *International Public Management Journal*.

From 1993 through 1997, Dr. Kelman served as Administrator of the Office of Federal Procurement Policy in the Office of Management and Budget. During his tenure as Administrator, he played a lead role in the Administration's "reinventing government" effort. He led Administration efforts in support of the Federal Acquisition Streamlining Act of 1994 and the Federal Acquisition Reform Act of 1995.

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Monsters in the Closet? The Impact of Collective Bargaining Agreements in A-76 Sourcing Decisions

Presenter: Lt. Col. Timothy S. Reed, USAF, 325th Contracting Squadron, is the Commander, 325 Contracting Squadron, Tyndall AFB, FL. He is responsible for $500M in annual purchases in support of F-15, F-22, and AWACS flight training. He entered the contracting field in 1993 through the Education with Industry Program, working as a student in the F-22 Engine Development Office at Pratt and Whitney Aircraft Engines in West Palm Beach, Florida. He has held various assignments in contracting, including the C-17 Systems Program Office. He created and served as director of the Air Force Strategic Purchasing Graduate Degree Program at the Air Force Institute of Technology. He has deployed as the director of Joint Contracting Command-North, Kirkuk, Iraq. He served as Deputy Chief, Procurement Transformation Division, Headquarters Air Force, where he was responsible for implementing strategic sourcing and commodity councils for the DoD and USAF. Lt Col Reed earned a PhD in Strategic Management and Entrepreneurship from the University of Colorado. He is a Certified Purchasing Manager, and is a distinguished graduate of Squadron Officer School and Air Command and Staff College.

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Abstract

Federal Government agencies convert in-house positions to contractor positions via the A-76 process in order to save money. During an A-76 conversion, stable future labor cost growth is assumed. This assumption is faulty in cases wherein the contractor workforce subsequently unionizes. Unionization may lead to unanticipated increases in cost, threatening the savings projected during the A-76 process. This study seeks to: 1) compare the rate of labor-cost growth for military, civilian, and contract employees and 2) compare current labor costs for a sample outsourced activity (fuels) to labor costs for the military requirement based on manpower standards. The study finds that overall, annual collective bargaining agreement (CBA) wages increases were typically 1-2% higher than *Service Contract Act* (*SCA*) wages increases. However, we found no evidence that contractors performed functions in our sample functional area at a higher cost than in-house. The actual cost of contractors averaged ~40% less than the cost derived from the military manpower standard. The actual in-house cost averaged over 20% higher than the cost derived from the manpower standard. Our results indicate that for the fuels functional area, A-76 actions remain economically advantageous to the government, despite increases in contract labor cost.

Introduction

In 1966, the US Government began using the A-76 process to evaluate governmental activities as candidates for outsourcing (OMB, 1983, August 4). The A-76 process provides a roadmap for government to convert work from internal (military in our study) performance to either contractor support or a redefined in-house performance organization. The intent of the A-76 process is to save money while freeing military personnel to perform inherently governmental functions. The A-76 process requires the use of estimates of future cost growth when evaluating cost not just in the current year, but in the out-years as well. These estimates are based on assumptions of stable future cost growth.

Several potential frustrations may develop for commanders in the post-A76 environment. These frustrations include a perceived loss of flexibility in mission support when moving from military to contractor support. Further, there may be frustration with “must pay” contract cost increases stemming from an increase in union-negotiated collective bargaining agreements (CBAs) and the perception that contractors have no incentive to

control CBA cost growth because the increase is passed on to the government agency as a 100% pass-through.

The impact of increasing labor costs for service contracts is felt Air Force-wide. Activities are competitively sourced for various reasons, but cost savings are a primary driver. When the cost of the contracted services expands beyond expectations, then only two options exist for the government: reduce the level of service or take funding away from other requirements. Both of these actions have a negative impact on day-to-day operations.

Loss of flexibility coupled with ever-increasing contract cost has caused some commanders to ask whether or not the A-76 evaluation process adequately considers future labor cost growth in the decision to outsource.

Wage Rate History

Wage rates in contracted-out functions are controlled by the *Service Contract Act* (*SCA*). The *SCA*'s purpose is to protect the wages and benefits of service contract employees. 41USC351 provides required provisions for public contracts in excess of $2500. The Secretary of Labor creates wage determinations to establish minimum wages for various categories of workers in a location**.** 41USC351(a) requires the contractor to provide wages and fringe benefits at least equal to the amounts established in the Department of Labor wage determination.

The *Fair Labor Standards Act* and *Service Contract Act, "*Price Adjustment (Multiple Year and Option Contracts)" clause incorporates this law into government contracts (*FAR,* 2007, 52.222-43). It applies to both contracts covered under the *SCA* as well as those under which the workforce is unionized, and it operates under a CBA. The contractor's employees are protected by these Acts as their pay and fringe benefits cannot fall below the wage determination of the Department of Labor. The contractor is protected by these acts because the increases in pay and fringe benefits are pass-through costs to the government. Thus, the contractor is not subject to financial ruin due to increasing labor/fringe benefit rates. The government takes on the financial burden of these increases to, in effect, protect the contractor's employees (Lear Siegler Services). This creates a financial obligation to the contracting entity which that entity has little input or control over. In *SCA* actions, the increases reflect the rise in wages in the local area per the wage determination, and are, therefore, seen as somewhat predictable. CBA negotiations between the contractor and the employees' union are not bound to such limitations, and are seen as less predictable.

Two additional *Federal Acquisition Regulation* (*FAR*) citations are very relevant. *FAR* 22.1008-2 (b) mandates that wage determinations and CBAs carry over even if there is a change in contractor due to the contract being reawarded. The intent here is clear: because the competing bidders are bound to the same labor rates as the incumbent, they cannot develop a bid advantage solely by discounting employees' wages. The effect of this, however, may be to reduce the incentive of the incumbent to drive a hard bargain in negotiations with the union. For one, they do not actually pay the increases, and secondly, their competition gains no advantage from the negotiated increases.

Finally, *FAR* 22.1002-3 and *FAR* 22.1021 do provide avenues for the government to ensure that the negotiations between the contractor and union are legitimate. *FAR* 22.1021 allows the contracting officer to request a hearing with the Department of Labor (DoL) to determine if the negotiated CBA rates are reasonable. The CBA will not be applied if:

> The Secretary of Labor determines—(1) after a hearing, that the wage and fringe benefits are substantially at variance with those which prevail for services of a similar character in the locality, or (2) that the wages and fringe benefits are not the result of arm's length negotiations. (*FAR,* 2007, 22.1002-3 (a) (1) (2))

The question of how much the wage and fringe benefit rates of collective bargaining agreements vary from the *SCA* rates raised by this *FAR* reference is at the heart of this research.

Three previous studies have addressed labor-cost growth issues and were referenced in this study. The first was conducted by the Center for Naval Analyses in 2001, entitled, "Long-run Costs and Performance Effects of Competitive Sourcing" (Rosenblum, Coast & Smallwood, 2001). The second study entitled, "Personnel Savings in Competitively Sourced DoD Activities: Are they Real? Will They Last?" was conducted by RAND in 2000 (Gates & Robbert). The third study referenced was conducted by Dr. Roger Golden and published in his dissertation entitled, "Cost Trends on Defense Commissary Service Contracts" (1999).

When the government converts work to contractor performance through the A-76 process, stable future labor cost growth is assumed. This assumption is faulty in cases wherein the contractor workforce unionizes. In addition, the assumption may lead to unanticipated increases in cost, which could invalidate savings projected during the A-76 process. Establishing a better method to compare future labor cost will ensure the more cost-effective organization, over the long term, performs the service.

The ultimate aim of this research stream is to develop an additional cost growth factor to consider in the A-76 process. This study focuses on answering two fundamental questions necessary to develop such a factor: Do CBAs lead to faster wage growth? Do CBAs end up costing the government more than military performance of the function?

Objectives

1. Compare cost growth in labor rates of military, civilian, *Service Contract Act*, and collective bargaining agreement employees.

2. Compare current labor costs for an A-76-affected activity to labor costs for the military requirement based on manpower standards.

The Sample: Air Education and Training Command (AETC)

The Air Force Air Education and Training Command (AETC) administers many contracts with industry for commercial functions. AETC has conducted A-76 competitive sourcing studies over a long period of time, with many being completed in the 1980's and 1990's.

The current challenge to AETC is that the government is required to pay the contractor for wage increases, whether they originate from a revised wage determination

under the *Service Contract Act* (*SCA*) or a renegotiation of a collective bargaining agreement (CBA). While the *SCA* is considered a fairly stable and predictable cost growth, the CBA growth is viewed as less predictable. For an organization with a defined budget, being required to fund unpredictable labor cost requirements can have negative impacts.

AETC's mission has led to frequent use of the A-76 process to competitively source commercial activities. Based on these factors, the study team selected AETC bases as the sample for this study.

Methodology

Assumptions

1. Direct comparison of base pay rates between military, civilian, *SCA*, and CBA employees is acceptable as a method of comparing labor cost growth. Because the composite factors for military pay contain costs not obtainable for civilian, *SCA* and CBA rates, the base pay rate is the most accurate measure for comparison between the contracted and in-house pay growth.

2. Time is not a factor in calculating labor cost growth rates as the comparison between rates covers the same time periods and, therefore, the time/inflation costs are the same.

3. *SCA* base pay rates plus health and welfare (H&W) costs are directly comparable to CBA base pay rates plus H&W costs. This assumption is necessary to allow for direct comparison of the two rates, although they may not always mean exactly the same thing for each CBA.

4. Overhead costs for Civilian, *SCA* and CBA positions are assumed to be relatively consistent, allowing comparison of wage increases without incorporating applicable overhead costs. This assumption is needed to conduct timely analysis.

5. The manpower standard for Fuels can be used as an independent comparison factor for the fuels function. The standard is not being used as a manpower adjustment tool as it is designed.

Objective 1: Cost Growth of Labor Rates

The first objective is to compare the labor cost growth in the various types of pay structures: military, civilian, contractor under *SCA*, and contractor under CBA. The purpose of this comparison was to determine if CBA wages increased at a higher rate than *SCA* wages and to compare that wage growth to military and civilian wage growth. The development of this comparison involved several steps.

The analysis was conducted by location because the pay scales and wage increases for *SCA*, and CBA employees varied by location. The first step was to identify AETC bases that had multiple CBAs. This is important because while the other three pay types are widespread, there are a limited number of CBAs. Some installations had just one CBA. Requiring a location to have multiple CBAs in order to be included is a precaution to prevent one aberrant CBA from skewing the location's comparison. After that, the pay increases

were calculated for each position and compared. The wages were also combined to analyze the wage growth for each type of pay over all of AETC.

The analysis of wage increases was conducted on base-pay rates and composite-pay rates. For base-pay rates, there are no fringe benefits (e.g., health and welfare costs) or overhead (e.g., FICA, SUDA, FUDA, etc.) costs included in the wages. For military wages, the base-pay rates did not include BAH, BAS, or any other fringe costs. For composite-pay rates, fringe benefits are included for all pay types, but the overhead costs are only included in the military pay rates. The overhead costs would be the same for *SCA* and CBA-determined wages because the contractor employing each position would not change.

Objective 2: Contractor vs. Military Cost Growth

The second objective was to compare actual contractor costs and actual military/civilian costs for a specific function to the manpower standard cost for that function. Although manpower standards are not recommended for A-76 competitions or reverse A-76 actions, this study used the manpower standard to contrast how in-house and contractor functions related to the standard. The manpower standard was used because manpower data was usually unavailable, outside of a limited timeframe, after the completion of an A-76 competition. The end result of this objective is a comparison of the actual costs of the function performed by military, civilian, and CBA employees to a calculated cost using the manpower standard.

The first step was to identify a function that, within AETC, is performed in-house at some locations while contracted out at others under collective bargaining agreements. The function had to have a relatively stable workload that could be easily quantified. The fuels function at AETC bases met these requirements, and as such was selected as a representative function for this study.

The next step was to calculate the manpower standards based on the Fuels Management Manpower Standard outlined in AFMS 41DA. The resulting manpower standards for each base were then converted to positions as described in AFMS 41DA. These positions were next converted to total cost. After that, the actual costs of the fuel functions at each base were compared with their respective manpower standard costs. For in-house costs, the assigned personnel numbers obtained from the AFPC Authorized and Assigned database were matched to position-costs to compute the actual costs of the in-house organization. For contracted-out costs, the actual contract costs were used.

Finally, the cost ratios of actual cost to projected costs using the manpower standard were calculated. These results were presented numerically and graphically.

Analysis

Objective 1: Cost Growth of Labor Rates

Of the AETC bases, seven bases provided data on three or more collective bargaining agreements: Columbus, Keesler, Lackland, Laughlin, Randolph, Sheppard, and Tyndall. Personnel at these locations provided the actual wage tables from the CBAs. Military base-pay and composite-pay tables were obtained through the Office of the Under Secretary of Defense (Comptroller) website (Office of the Under Secretary of Defense, 2007). The civilian pay was comprised of Non-appropriated Funds (NAF) pay tables,

Appropriated Funds (AF) pay tables and General Schedule (GS) pay tables. These civilian base-pay tables were obtained from the Department of Defense (DoD) Civilian Personnel Management Service Website, and the fringe rates were obtained from the Office of Management and Budget (OMB) transmittal M-07-02 (Civilian Personnel Management, 2007). The *SCA* pay tables and fringe rates were obtained from the DoL– *SCA* Wage Determinations website (Wage, 2007).

Next, all the base and composite pay tables were aggregated by year and the pay increases for individual positions or grades were calculated. The mean increase for each position or grade was computed to form an overall rate of increase for each year. This process was repeated for the civilian, *SCA* and CBA pay at the seven different bases and the results were tabulated and graphed.[41]

Analysis of the four pay types occurred in three phases. First, the average pay increases, by position, for each pay type were analyzed by year. This analysis was not conclusive because pay types such as *SCA* didn't get pay raises every year. Often, the *SCA* pay increases occurred every two years in large increments. Thus, the graphs resulting from this phase of analysis were not static and did not reveal any significant trends.

The next phase of the analysis was to calculate the cumulative wage increases for each pay type. This was done by compounding each pay increase by that of previous years to reveal the overall growth over time for each position. A challenge was encountered in this phase of the analysis: not all bases had CBA wage history from FY99 to FY06. Thus, the cumulative wages for these bases did not start until the CBA history began, which created a lag in the graphs.

The final phase of the analysis was to adjust the CBA wage increases for years without CBA wage history. To better represent the CBA wage increases, the CBAs were assumed to follow *SCA* wage increases for the years that the CBAs were not in effect. This was a safe assumption because contracted employees would have followed *SCA* wage rates before unionization. Also, Tyndall AFB did not have any *SCA* or CBA wage history available for FY00 or FY01. To account for this, *SCA* and CBA wage increases were each conservatively assumed to be 3.0% for both years.

The results for all seven bases were combined and are shown in Figures 1 and 2. The Bureau of Labor Statistics (BLS) line on each graph represents the DoL-reported wage inflation rate, nation-wide, for each year.

[41] Individual results for each base are available from the authors.

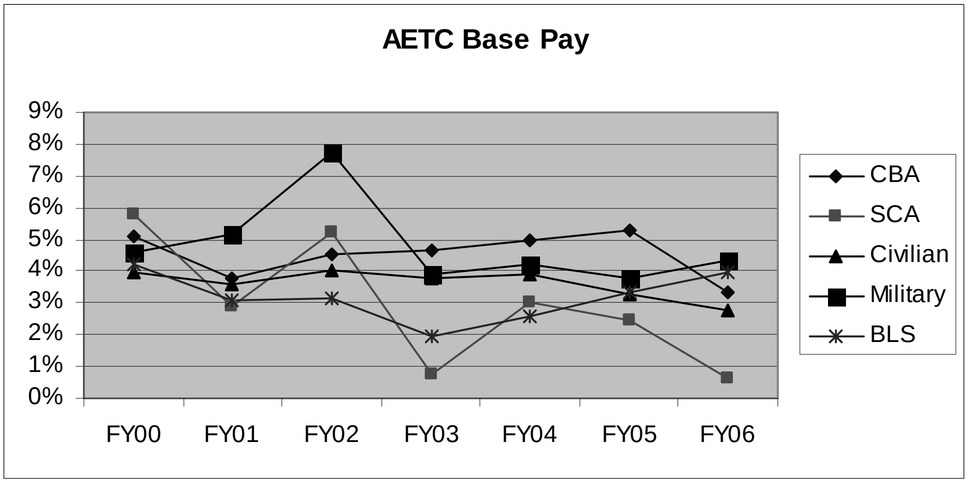

Figure 8. AETC Base-pay Increases by Year

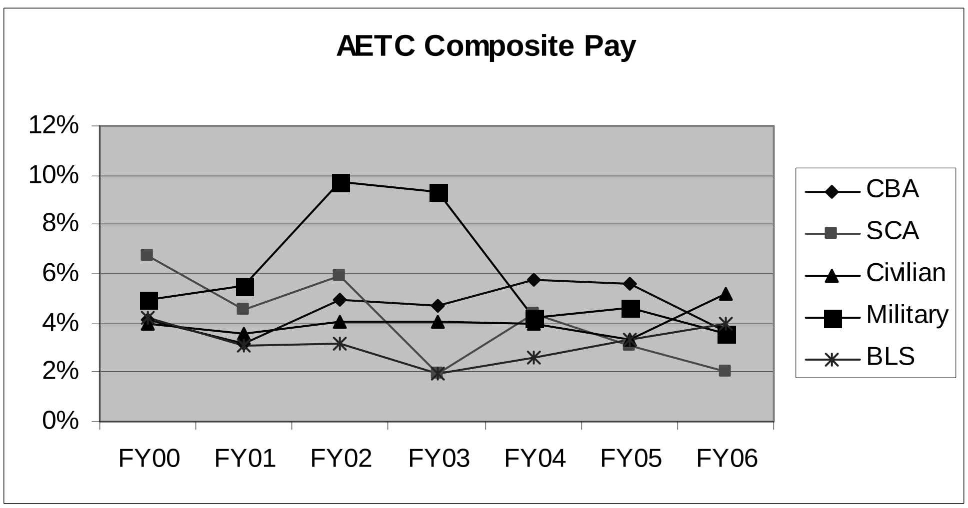

Figure 9. AETC Composite-pay Increases by Year

The next step was to look at the cumulative pay increases over time. To do this, the rate of increase for every year is compounded by the rates of increase for the previous years. This step assists in showing the total increase over time for each category of employee. The results of this analysis are shown in Figures 3 and 4.[42]

[42] Individual results for each base are available from the authors.

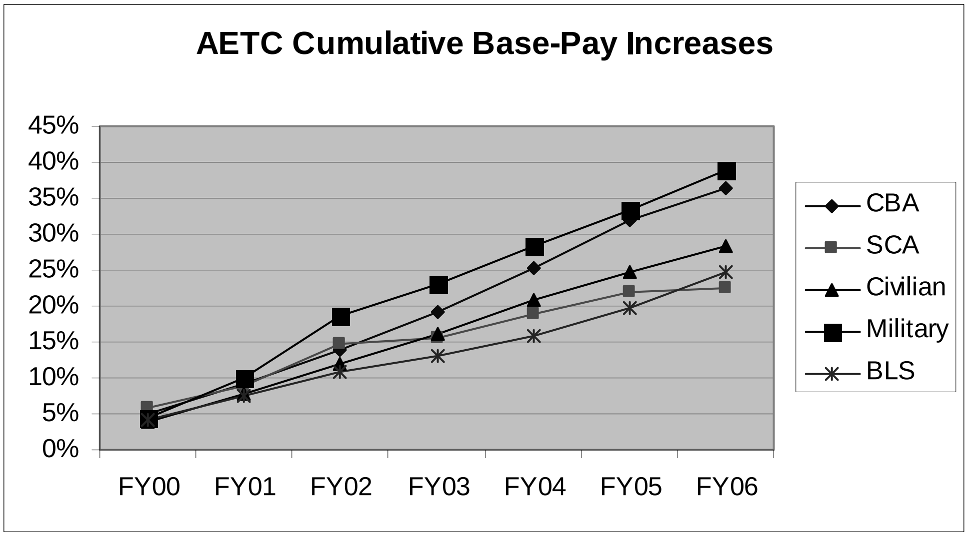

Figure 10. AETC Cumulative Base-pay Increases

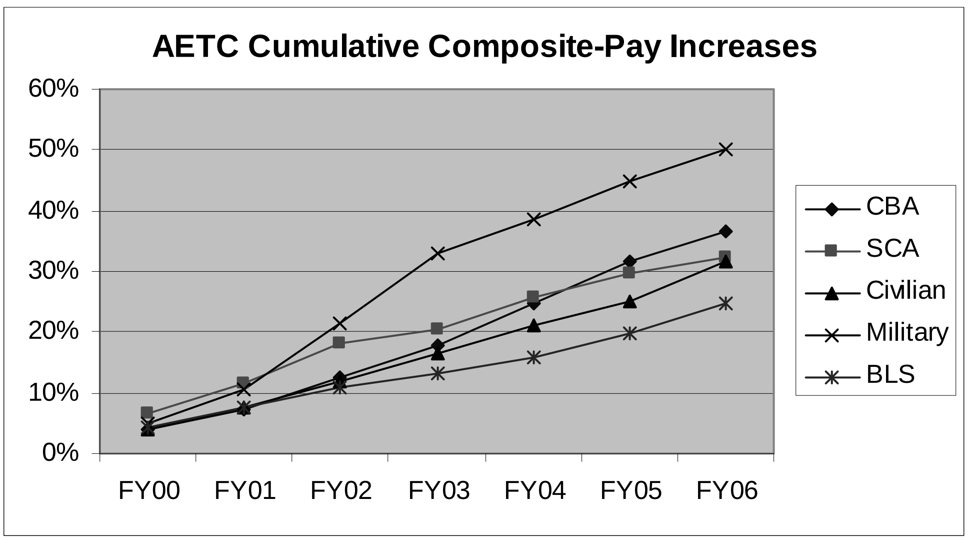

Figure 11. AETC Cumulative Composite-pay Increases

One challenge existed in this cumulative-pay analysis; some bases did not have any CBAs for FY00, FY01 or FY02. To better represent the CBA wage increases, the CBAs are assumed to follow *SCA* wage increases for the years that the CBAs were not in effect. This is a safe assumption because contracted employees would have followed *SCA* wage rates before unionization. Also, as mentioned previously, Tyndall AFB did not have any *SCA* or CBA wage history available for FY00 or FY01. To account for this, *SCA* and CBA wage increases are each conservatively assumed to be 3.0% (lower than the BLS) for both years. The results of these adjustments are shown in Figures 5 and 6.

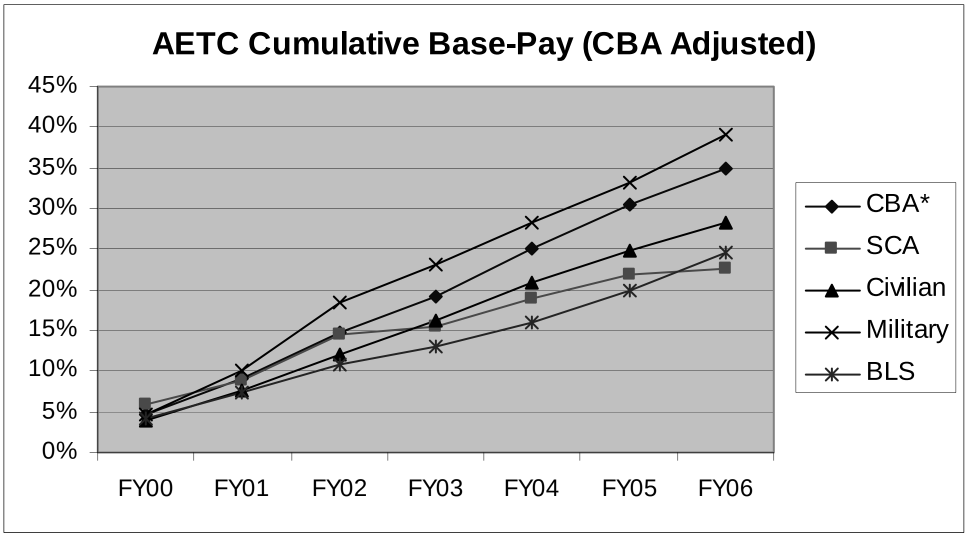

Figure 12. AETC Cumulative Base-pay Increases (CBA Adjusted)

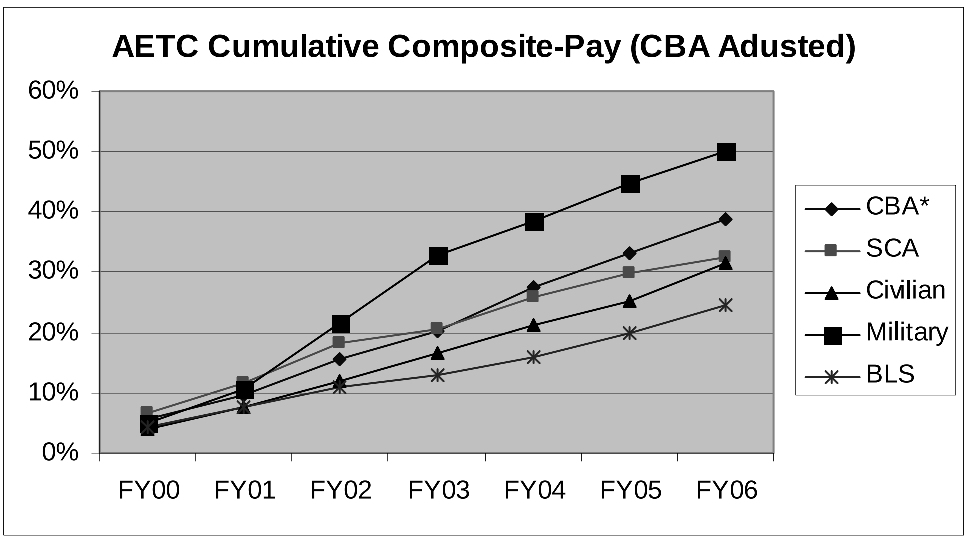

Figure 13. AETC Cumulative Composite-pay Increases (CBA Adjusted)

Figures 5 and 6 show that CBAs have increased at a slightly higher rate than the *SCA* wages, and the military pay rates have increased at a higher rate than any of the other pay types. Table 1 shows the cumulative base- and composite-pay increases from FY99 to FY06.

Pay Type	Cumulative Base-pay Increases	Cumulative Composite-pay Increases
Military	38.98%	50.03%
CBA	34.99%	38.87%
Civilian	28.21%	31.65%
SCA	22.63%	32.35%
BLS	24.60%	24.60%

Table 1. AETC Cumulative Pay Increases from FY99 to FY06

Objective 2: Contractor vs. Military Cost Growth

Seven AETC bases have contracted out for their fuels support (Columbus, Laughlin, Maxwell, Randolph, Sheppard, Tyndall, and Vance). All of these workforces operate under collective bargaining agreements. However, two of these bases (Maxwell and Tyndall) operate under BOS (Base Operations Support) contracts that combine many functional areas under one contract line-item. This made the fuels costs at these two bases difficult to clearly identify. As a result, Maxwell and Tyndall AFBs were eliminated from the study. Six AETC bases perform the function in-house with military and/or civilian personnel (Altus, Goodfellow, Keesler, Lackland, Little Rock, and Luke).

The manpower standard for the fuel function is not an accurate predictor of the number of personnel required for smaller workloads because it starts with ~27 positions as a baseline regardless of the workload. Thus, because Goodfellow AFB handles considerably less fuel than the other AETC bases (which skews the data), it was excluded from the analysis.[43] The remaining pool for analysis consisted of five in-house bases and five collective bargaining agreement bases. With the assistance of the Manpower flight at Maxwell AFB and the fuels functional chief at AETC, the standard manpower costs for each of these ten organizations were calculated using the composite-pay figures for military and civilian personnel. The results are in Figure 7.

Figure 7 indicates that the Fuels function is varied at the eight bases examined. From Altus, with an annual calculated manpower standard cost of nearly $5 million dollars, to Keesler, with an annual calculated manpower standard cost of just over $2 million, the workload is wide-ranging at AETC locations.

[43] At Goodfellow, all fuels functions are performed by one person, a GS-7.

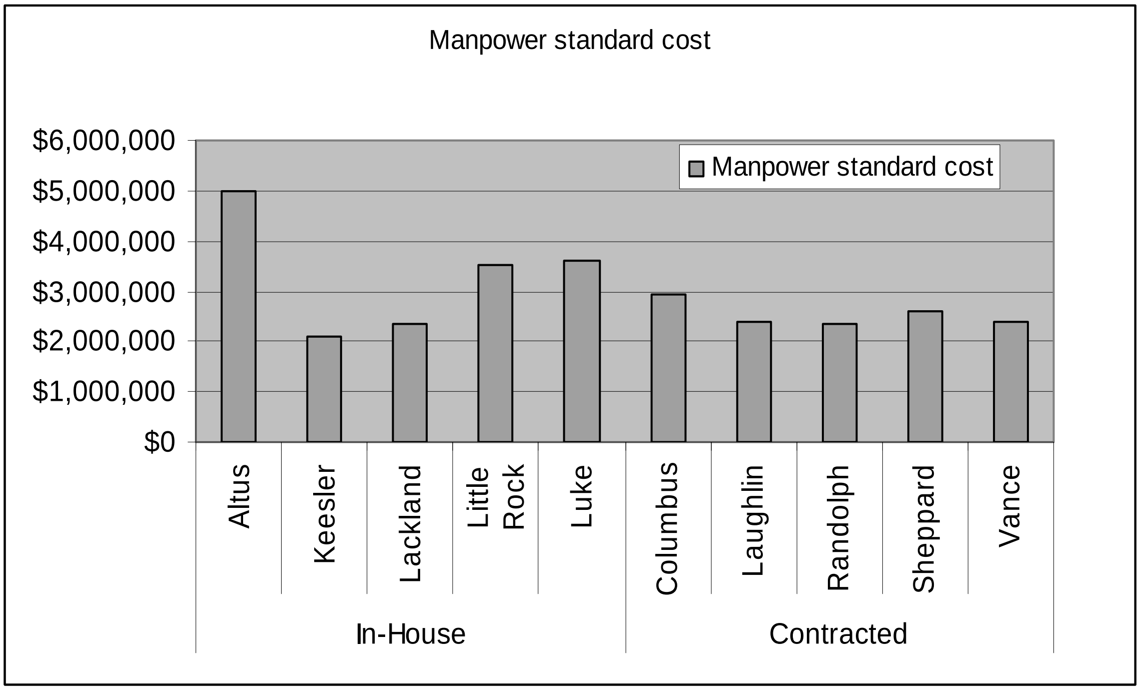

Figure 14. Manpower Standard Cost

The fuels function at ten AETC bases was analyzed by comparing actual FY06 costs to their respective manpower standard-derived costs. Five of the bases analyzed had contracted fuel organizations, and the other five had in-house fuel organizations. In the first step, manpower standards were calculated using the Fuels Management Manpower Standard outlined in AFMS 41DA. The resulting manpower standards were then converted to positions as described in AFMS 41DA, and the positions were next converted to total cost.

Next, the actual cost of each organization was compared to the calculated manpower standard cost. For contracted organizations, the actual FY06 contract costs were used in the comparison. For in-house organizations, the assigned personnel numbers obtained from the AFPC Authorized and Assigned database were used to compute the total personnel costs.

Finally, the cost ratios of actual cost and manpower standard-calculated costs were calculated, revealing that contractor costs remain economically advantageous to the Air Force.

The next step in the calculation was to calculate the actual cost of manpower at those locations that are manned by in-house personnel. With assistance from AETC fuels personnel and the Air Force Personnel Center’s Assigned/Authorized data source, the actual cost for labor for FY06 was calculated for each of the five bases. Again, the composite pay rates are used in this calculation. The results are in Figure 8.

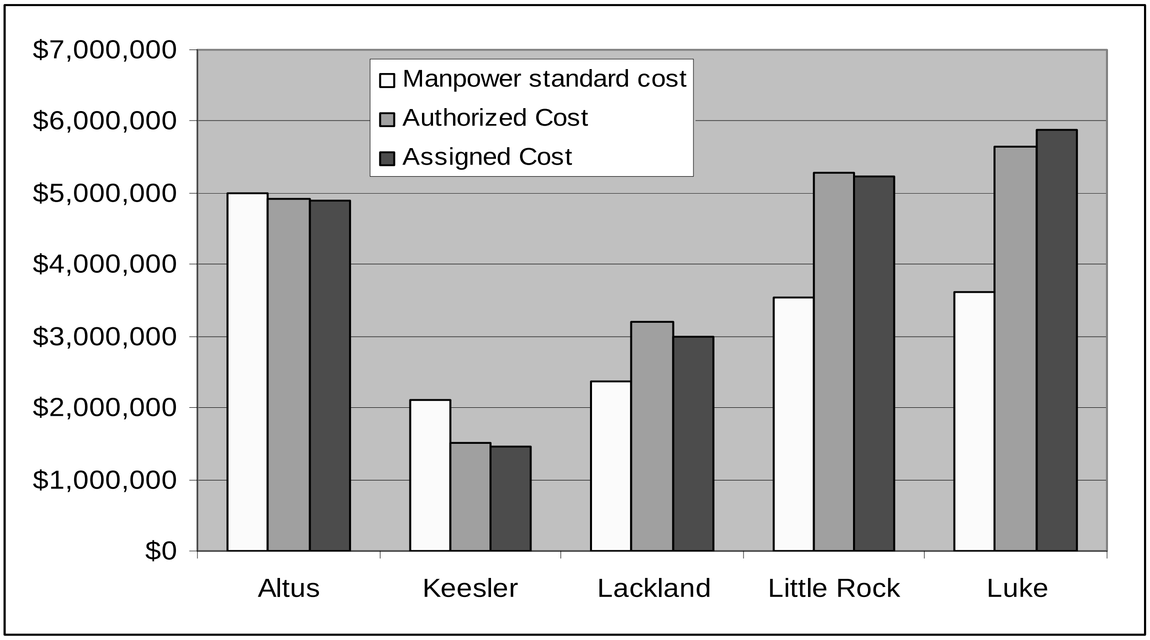

Figure 15. Manpower Standard Costs vs. In-house Costs at In-house Organizations

A similar comparison was then made between the contracted organizations and their calculated manpower standard costs. This comparison is shown in Figure 9. Table 2 then compares the percentage of the calculated manpower standard cost to the actual organization cost. This comparison uses the assigned-personnel cost for in-house organizations, as this more accurately captures the cost to the Air Force.

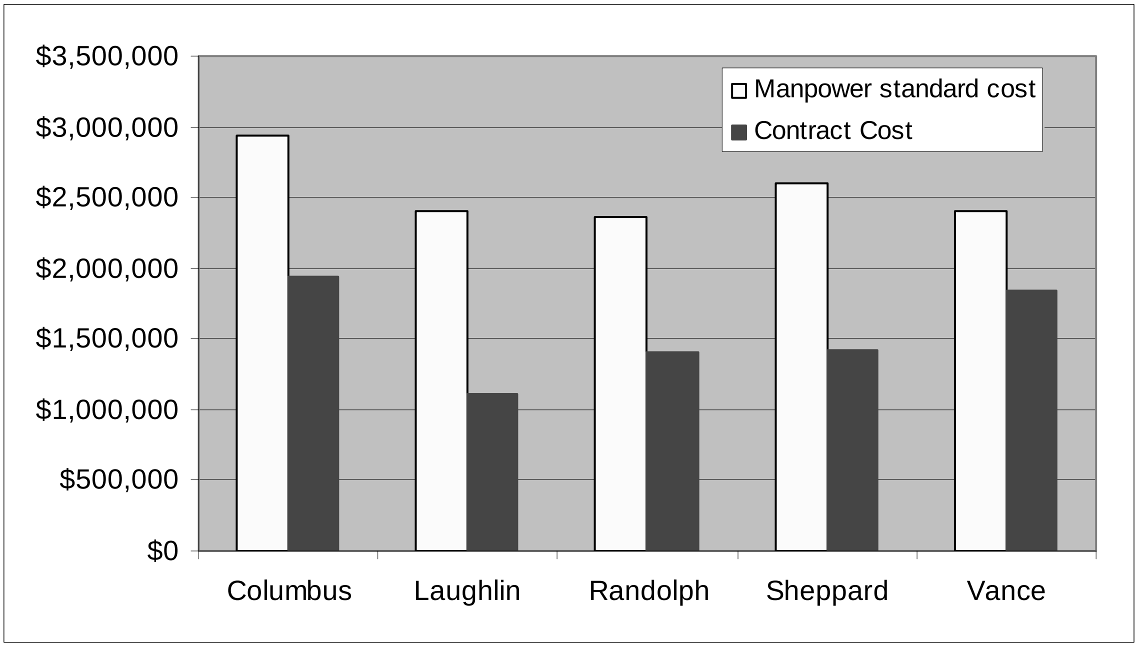

Figure 16. Manpower Standard Cost vs. Contract Cost at Contracted Organizations

Base	In-house	Contracted	Percentage
Altus	X		97.8%
Columbus		X	66.2%
Keesler	X		69.2%
Lackland	X		127.2%
Laughlin		X	46.1%
Little Rock	X		147.5%
Luke	X		162.2%
Randolph		X	59.4%
Sheppard		X	54.6%
Vance		X	76.6%

Table 2. Percent of Actual Cost vs. Manpower Standard Cost

The in-house bases averaged 123.0% of the hypothetical manpower standard cost. As seen in Table 2, Keesler AFB is the only in-house organization to perform the function at a considerably lower cost than dictated by the manpower standard. This is possibly a result of the inherent flaw in the manpower standard for organizations with smaller workloads. The contracted organizations averaged 60.7% of the hypothetical manpower standard cost. Thus, using the manpower standard cost simply to contrast how in-house and contractor actual costs compared to the standard, contractor costs are still economically advantageous overall for the sampled fuel functions.

Findings

Objective 1: Cost Growth of Labor Rates

There was an observed trend of CBA wages growing at a faster rate than *SCA* wages. Typically, annual CBA base-pay increases were 1.76% higher than the *SCA* base-pay increases. The analysis showed that the annual composite-pay increases were ~1% higher in CBA positions than in *SCA* positions. This trend is probably more significant than shown considering the initial jump in wages that often occurs when *SCA* positions unionize. When positions unionize, the CBA usually negotiates a one-time spike in wages before leveling off. This *SCA*-to-CBA wage jump was not captured by our analysis because the conversion usually involved a position-name change, preventing direct comparison. The military and CBA wage increases appeared to be the fastest growing of the four pay-types investigated at the seven bases.

Objective 2: Contractor vs. Military Cost Growth

There was a trend that contractors performed fuel functions at a lower cost than in-house in comparison to their calculated manpower standard costs. For contracted services, the actual cost of contractors averaged ~40% less than the cost derived from the manpower standard. For in-house services, the actual in-house cost averaged over 20% higher than the cost derived from the manpower standard. Thus, in these cases, the A-76 actions still appear to be economically advantageous to the government.

Limitations

1. Manpower data is difficult to obtain outside of a limited timeframe. This limits the ability to develop an in-house organization comparable to a contracted organization without significant investment of time and expertise.
2. Contract data is limited in its timeframe. Contracting files are maintained in accordance with the *Federal Acquisition Regulation*. The timeframe of the study is limited to the years that the data is available.
3. There is a limited sample size available for the study. It only includes those service contracts within AETC that have CBAs. The size was further constrained to those locations where multiple contracts exist. This limitation and constraint restricts the general application of the results of the study.
4. Changes in position names/job titles when contractor positions unionize prevent a direct comparison of *SCA* and CBA wage growth.
5. All military and civilian pay grades were analyzed, but not all pay grades would typically be converted to service contract positions.

Conclusion

This study takes important preliminary steps toward determining whether an additional A-76 competitive sourcing process factor to account for future contract cost growth should be developed. We found the research highly challenging due to the lack of

historical documentation in all areas. The documents recording the manpower assessment at the heart of the A-76 process is almost never available. The assumptions used by evaluators relative to future labor cost growth at the time of the A-76 decision are difficult to acquire, if not impossible. As such, it is difficult if not impossible (perhaps by design) to conduct an assessment of how closely the assumptions at the time of the A-76 track the actual post-decision labor increases. As such, it would be difficult to develop a factor to adjust the assumptions used by evaluators if we cannot determine what the initial assumptions were.

A common perception in the DoD is that CBA cost growth in the out-years makes outsourcing less attractive financially. This study finds that while CBA cost growth is substantial, in our sample functional area, CBA cost growth lagged behind the cost growth of military labor. One explanation may be that while commanders are forced to deal with the realities of increasing contract costs at the MAJCOM and local level, they may be less aware of the challenges of dealing with the even more substantial increases in military personnel costs, which are often dealt with at the Air Staff level.

A final finding of note is that government service civilian cost growth lagged behind both military and contract labor growth, indicating that over time, civilian labor may prove to be the most stable of the three labor types considered. Our findings do indicate that future cost growth is not stable; however, it appears to be instable in both military and contractor labor pools. As such, should a factor be pursued to provide better insight into the future cost of contractor labor, one should also be pursued to provide better insight into military labor cost.

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Does Competitive Sourcing Really Pay?

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Executive Summary

The Office of Management and Budget (OMB) *Circular A-76*, *Performance of Commercial Activities,* has been around for over 40 years. *A-76* was commonly used to refer to the process of outsourcing non-inherently governmental jobs in the 1990's. The *A-76* circular was substantially revised to simplify and standardize implementation guidance and was released in its current form on May 29, 2003. The OMB now uses *A-76* to help implement the competitive sourcing initiative on President Bush's Management Agenda. The stated policy objective in the revised circular is, "To ensure that the American people receive maximum value for their tax dollars, commercial activities should be subject to the forces of competition" (OMB, 2003, May 29). The purpose of this study is to determine if *A-76* competitions have resulted in saving the taxpayers money. More specifically, has *A-76* saved the Department of Defense (DoD) money over the long term?

The thinking goes that by subjecting the non-inherently governmental jobs being performed by government employees to the "forces of competition," the American taxpayer should benefit in the form of better service at lower cost. As stated in the *Federal Acquisition Regulation* (*FAR*), "Commercial activities should be subjected to the forces of competition" (Part 7.302). In this study, I will be primarily concerned with the lower cost expectation and some of the broader policy implications of this strategy.

So the question is: have *A-76* competitions saved the DoD money? A General Accounting Office (GAO) report in 2000 on *A-76* studies in the DoD concluded that the Department had saved $290 million dollars on 286 studies conducted from 1995 to 1999. However, the study goes on to say that there were some problems in the way the Government calculated baseline costs, which were often based on authorized positions rather than on actual positions, and that the cost-savings estimates did not include the costs of conducting the studies or the cost of implementing and managing them (GAO, 2000). In other words, true cost savings must consider the costs of conducting the studies and the costs of administering the contracts or otherwise monitoring performance. It was also, "noted that the level of savings will be difficult to track in the long term because workload requirements change, affecting program costs and the baseline from which savings are calculated" (2000).

A more recent study conducted by the IBM Center for The Business of Government found that competition results in significant savings. This study examined competitions conducted from 1994 though the first quarter of 2004 and used the DoD's own data-collection system to conclude that there was, "an average estimated savings of 44 percent of baseline costs, for a total savings of $11.2 billion" (Gansler & Lucyshyn, 2004, October, p. 28, 32). The study also found that although there were relatively few government civilian employees involuntarily separated, most of the savings associated with the competitions came as a result of reducing the number of positions by 24,852 (2004, October). The number of positions was reduced regardless of who won the competition—the government or a contractor. The savings estimate was also based on estimated cost and did not consider the cost of conducting the study or administering the contracts.

In another report (GAO-04-367), the GAO indicates that although the DoD has achieved savings though competitive sourcing, it is difficult to estimate precisely the amount of these savings (2004). Further, the Office says significant challenges face the agencies implementing competitive sourcing, including: difficulty in identifying non-inherently governmental positions for competition, a constantly changing environment, insufficient staff to plan and carryout the competitions and a lack of funding to implement and administer the program (2004).

In a widely publicized White Paper, the Office of Management and Budget (OMB) looked at 217 competitive sourcing studies conducted in FY 2004 and estimated these studies would "generate a net savings," or cost avoidance of $1.4 billion over three to five years (2005, January). They claim that the data suggests the savings are primarily because of larger competitions and more frequent use of standard competitions that require in-house teams to come up with a most efficient organization. Put another way, "competition drives bid prices down and efficiencies up" (2005, January). It remains to be seen whether or not this will remain true over the life of the contracts.

An interesting study by David Galley (2002), an adjunct faculty member at George Washington University, examined the impact of public-private competitions on the costs of providing maintenance and repair services for buildings on 104 Army installations from 1989 to 1999. He says that the study, "shows conclusively that the impact of those *A-76* competitions on costs depended on the category of the winner" (pp. 3-18). If the private sector won, there was significant cost savings; but if the work was kept in-house, there was not (2002). One offered explanation for this was that the Army did not monitor the in-house work force's performance like it did when a contractor was involved.

A study at the US Air Force Academy examined five different studies conducted during FY 2001 to 2003 which resulted in significantly reducing the number of employees performing competitive sourcing functions. However, a survey of employees and managers familiar with the competitive sourcing programs indicated that 80% felt the services were worse than before the studies had been done and only about half thought the program saved money for the Air Force (Green, Heppard & Forrester, 2004, pp. 4-11). In one conclusion, this study also indicated that, "Estimates used to compute savings omit many costs, e.g., study costs, retraining costs, loss of productivity, severances packages, etc." (2004).

In a briefing paper entitled *Show Me The Money,* Max Sawicky of the Economic Policy Institute investigated the evidence presented by the Office of Management and Budget (OMB) in support of the *Revised A-76 Circular* that purported to show that *A-76*

competitions saved money. One of the studies cited in this paper was conducted at the Center for Naval Analysis (CNA) and involved 16 competitions for 2,800 jobs. His findings indicated that in every case, the "observed cost" (or the actual cost of performance) exceeded the bid price. The "effective cost" (the actual cost taking into consideration the change in the scope of work) exceeded the bid price in nine out of fourteen cases (Sawicky, 2003). An interesting observation in this study was that even if there are apparent savings, they are not returned to the taxpayer. In effect, competitions are really a vehicle for expanded government because, "agency savings do not translate into budget savings" (2003, p. 8, 12).

In light of these and other studies on outsourcing in the DoD, it is interesting that a recent article in the *Federal Times* asserts that according to a Pentagon official, "it's unclear if the military always saves money when it contracts with private companies to perform support services." Claude Bolton, assistant secretary of the Army for acquisition, logistics and technology, is quoted as saying that, "While it may be clear that a particular contract will save millions of dollars right away, there is no simple way to determine if that remains true four or five years down the road" (as cited in Lubold, 2006, p. 13). In other words, estimated savings at the beginning may not translate into actual savings in the end.

"Ah, there's the rub." Federal employees unions and others have been making this case for years. Testifying before Congress, the president of the American Federation of Government Employees, Bobby Harnage (2001, March 15), indicated that even as the number of federal government employees in the DoD steadily decreased by over 280,000 from 1992 to 1999, the cost of service contracts increased from $39.9 billion to $51.8 billion (p. 1). In the DoD, service contracts are now the largest segment of DoD procurements and make up over 50% of all contract dollars awarded (Lubold, 2006, April 24, p. 13). In fact, according to a recent congressional report, spending on federal contracts has been the fastest growing part of the discretionary budget for the last five years, and service contracts are leading the way (US House, 2006). As anyone familiar with the federal budget can tell you, the budget has not gone down regardless of how many jobs are contracted out or how many activities are turned over to contractors. In the DoD, budgets have increased almost every year since 1994, and they are not expected to go down anytime soon (OMB, 2005).

So, does outsourcing or competitive sourcing really save the taxpayer money? It may save money on some contracts, but there is a question about whether the government customer is getting the same or better service. Also, projected savings and actual savings are two entirely different things. The comptroller general of the United States, David Walker, was quoted recently as saying, "they (contractors) often fail to deliver the promised efficiency and savings. Private companies cannot be expected to look out for taxpayers' interests" (as cited in Shane, 2007, February 4). Generally, it does not appear *A-76* is saving the taxpayer money overall. As pointed out above, the federal budget is not decreasing, in spite of the hundreds of thousands of jobs that have been contracted out. Both Congress and the Executive branch like to tell voters they are cutting the bureaucracy, but in reality they are merely transferring government functions to private contractors. This growing "shadow workforce" has been identified by many writers, but Paul Light of the Brookings Institute has been a leader in this area; he has an excellent book on the subject entitled *The True Size of Government,* in which he concludes, "the true size of the government is much larger than the federal employee headcount suggests" (1999, p. 44).

There is an old saying in Washington that, "there are two kinds of contractors, those with government contracts and those that want government contracts." The fact that the

federal government is the largest purchaser of goods and services in the world makes it a very attractive customer. The implication that by subjecting non-inherently governmental jobs to the forces of competition somehow captures market efficiencies is on its face plausible; but on closer examination, this implication may be more apparent than real. First, as stated by Professor Dan Guttman of Johns Hopkins University in a recent article, although, “we associate the utility of contractors with the notion that the private sector brings market forces to bear on government activities, this is only true where a commercial market exists for the government purchases” (2004, p. 24). He goes on to say, “where government is the primary or predominant purchaser of services or goods the picture is less clear” (2004). As has been demonstrated by Peck and Sherer (1962) in their classic analysis of weapon system procurement, markets are difficult to duplicate in a governmental setting primarily because the government entity really doesn’t have any market competition for many of the products they buy. As they point out, the government is often the only buyer (p. 60). This rational can also be applied to services the government purchases. For instance, typically the work (services) is to be performed on a government installation; the work will be performed during certain hours, and the work is controlled by a performance work statement or statement of work with some type of government monitoring. The services may even be performed in a combat environment. This is not exactly “market conditions.”

Secondly, as has been asked by others and included in Dan Guttman’s article, “In what respect is a contractor that earns nearly 100% of its income from doing government work engaged in a commercial activity?” (2004, p. 29, quoting from the “Bell Report”). Third, if the government can manage its organization better by creating a “most efficient organization,” why isn’t it doing so already?—because, as has been shown (See IBMCBG study cited above), most of the alleged savings comes from reducing the number of employees. Fourth, the whole debate about what is inherently governmental varies from time to time and place to place. There is conflicting guidance from agencies on what is inherently governmental, and some of it even seems to be in conflict with the *Federal Acquisition Regulations*. And finally, social and economic policies like equal employment opportunity, veteran’s preference, providing jobs for the handicapped and disabled, health insurance and retirement benefits for employees are now discounted in the name of competition. Is this really what “competitive sourcing” is supposed to be about?

Competitive sourcing (or, as it used to be called, “commercial activities”) is about private-sector contractors doing commercial work. This should not be that hard to define. Like Lt. General Donald Hoffman, military deputy in the office of the assistant secretary of the Air Force said, “We don’t need Air Force plumbers and Air Force electricians when right outside the gate there is a contractor to do that stuff” (as cited in Lubold, 2006, p. 13). I think he is right. Those are excellent examples of commercial activities. But simply because some contractors want more government work, and some government officials want to give it to them (for a variety of reasons), that still doesn’t make almost everything the government does a commercial activity. It is high time that the public and their elected representatives recognize that reducing the size of government is about more than eliminating federal employees before it’s too late. In fact, a good first step might be for congress to take the recommendation of their own analysts and, “further prescribe that certain government activities are to be considered inherently governmental” (Grasso, 2003, October 20, p. 23). This would remove the arbitrary discretion of understaffed agencies looking for a way to outsource their work, and perhaps save us from ourselves, while making sure all the agencies use the same criteria when determining what jobs are to be outsourced.

Although it may be unpopular to say that the government has a higher calling than the purely monetary incentive of business to make a profit, it is nevertheless true. The government typically has a mission to accomplish, and it may not be financially feasible from a business point of view. When this is the case, why should taxpayers be expected to not only pay for the service but to also pay a profit? This is especially true when the services being performed are not really commercial services. For competitive sourcing to really work, the first step must be, as Professor Steven Schooner has indicated, “to determine which functions are inherently governmental and which are not” (2004, p. 295). It should not be that difficult to identify a commercial service or activity. Then, “the government should begin outsourcing those services that are most readily available in the private sector” (2004, p. 296). This is the only way the government can truly benefit from “market forces.” To try to compete jobs that are not typically performed in the private sector is not in the public interest and will not save the taxpayer money in the long run.

Beyond the cost savings or cost avoidance that may or may not be associated with competitive sourcing, there is the question of what is in the best interest of the government and the public. On this point, an outsourcing survey conducted by Deloitte Consulting Corporation of 25 world class organizations found that, “outsourcing is an extraordinarily complex process and the anticipated benefits often fail to materialize” (2005, April, pp. 3-4). Further, they say, “In the long run, organizations that continue to outsource will experience a loss of bargaining power to vendors as the supply side consolidates” (2005, April). Both of these phenomena have occurred in the Defense industry in over the past 20 years and, “it is unlikely that the defense industry will ever approximate a competitive market” (Driessnack & King, 2004, January-April). As the supply side continues to consolidate domestically and internationally, is it really in our national interest to contract out more and more government activities? Perhaps the debate we should be having is what is in our national best interest from the taxpayer’s point of view—because as we have seen, the cost of government is not going down.

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Panel 10 - Evolving Technologies in DoD Acquisition

Wednesday, May 16, 2007 3:30 p.m. – 5:00 p.m.	**Panel 10 - Evolving Technologies in DoD Acquisition** **Chair:** **Lorna B. Estep**, Deputy Director for Supply, Directorate of Logistics and Sustainment, Headquarters Air Force Materiel Command **Discussant:** **Michael A. Schwind**, Vice President, Federal Sector, UGS Corporation **Papers:** ***Optimal Inventory Policy for Two-echelon Remanufacturing*** **Geraldo Ferrer**, Naval Postgraduate School ***B2B Models for DoD Acquisition*** **Magdi N. Kamel**, Naval Postgraduate School

Chair: Lorna B. Estep, Deputy Director for Supply, Directorate of Logistics and Sustainment, Headquarters Air Force Materiel Command, is responsible for the Materiel Support Division of the Supply Management Activity Group, a stock fund with annual sales of $7 billion. She directs a wide range of logistics services in support of Air Force managed spare parts, to include transformation programs, requirements determination, budgeting, acquisition, provisioning, cataloging, distribution and data management policy. She also provides supply chain management policy, guidance and direction in support of headquarters, air logistics centers, and U.S. Air Force worldwide customers.

Ms. Estep started her career as a Navy logistics management intern. She has directed the Joint Center for Flexible Computer Integrated Manufacturing, was the first program manager for Rapid Acquisition of Manufactured Parts, and has served as Technical Director of Information Technology Initiatives at the Naval Supply Systems Command. In these positions she has developed logistics programs for the Department of Defense, implemented one of the first integrated and agile data-driven manufacturing systems, and directed the development of complex technical data systems for the Navy.

As the Director of Joint Logistics Systems Center, Ms. Estep had the duties of a commanding officer for a major subordinate command. In addition, she acted as the Logistics Community Manager, an emerging organization to coordinate and implement the revised Defense Department logistics strategy for achieving Joint Vision 2010 through modern information techniques and processes. She has also served as Chief Information Officer for the Naval Sea Systems Command in Arlington, Va., and Executive Director of Headquarters Materiel Systems Group at Wright-Patterson AFB. Prior to her current assignment, she served as Deputy Director for Logistics Readiness at the Pentagon, where she developed combat support concepts, doctrine, and sustainment policy with the Office of the Secretary of Defense, defense agencies, the Joint Chiefs of Staff and combatant commanders.

Optimal Inventory Policy for Two-echelon Remanufacturing

Presenter: Geraldo Ferrer, Naval Postgraduate School. Professor Ferrer's areas of expertise include global operations, supply-chain management, sustainable technologies, product stewardship, reverse logistics and remanufacturing. He also has studied the reverse logistics required in recycling and remanufacturing operations, and inventory problems affecting products made in small batches for frequent just-in-time deliveries.

He has published on these topics in *Management Science, European Management Journal, Naval Research Logistics, IIE Transactions, Production and Operations Management, European Journal of Operational Research, International Journal of Production Economics, Ecological Economics, Business Horizons* and *Resources Conservation and Recycling*. He is a contributor in the *Handbook of Environmentally Conscious Manufacturing* and *Handbook of Industrial Ecology*.

He has presented his research in national and international conferences in four continents, and in invited seminars in various academic institutions. Dr. Ferrer serves as reviewer in many academic journals, for the *National Science Foundation* and for the *Social Sciences and Humanities Council of Canada*. He has also reviewed textbooks in the areas of operations management, inventory management and project management.

Dr. Ferrer has consulted for companies in the United States on waste reduction and reverse logistics issues. He was founder and director of Superserv Ltd., a company that promoted technology transfer ventures between North American and Brazilian business, introducing innovative technology products in Brazil.

He received his PhD from INSEAD, MBA from Dartmouth College, a mechanical engineering degree from the Military Institute of Engineering in Rio de Janeiro and a BA in Business Administration from Federal University of Rio de Janeiro.

Prof. Geraldo Ferrer was in the faculty of the Kenan-Flagler Business School at the University of North Carolina for seven years and is now a faculty member of the Naval Postgraduate School.

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Abstract

We present a two-echelon remanufacturing facility subject to constant demand, in which the disassembly process and the repair process observe stochastic yield. We develop an intuitive scheduling policy and perform a robustness test.

Keyword: inventory management, multi-echelon, remanufacturing, product recovery, stochastic process yield, financial holding cost, physical holding cost

Introduction

Yano and Lee (1995) revised several lot-sizing models in which production yield is random. A large number of those models were inspired by the difficulties faced in the production of electronic components, where the production yield in some stages may be

very low. A similar situation occurs in remanufacturing sites. Cores entering the remanufacturing shop enter a pre-selection stage in which some disassembly takes place. The disassembly modules are stocked close to the renovation area, where they are repaired and made ready to reuse. One particularity of the remanufacturing shop is the different ways that the inventory held in stock affects the operating cost, whether it is before or after the final production stage. Most of the holding cost in the upstream operation refers to the physical handling of a large number of assemblies that occupy a significant amount of space, but might not survive the remanufacturing process. Meanwhile, most of the holding cost in the downstream operation refers to the opportunity cost of the resources committed to adding value to the sub-assembly renovation.

The remanufacturing shop that we described has not been modeled yet. The paper we propose contributes in this literature by providing a simple policy with two control variables: the lot size in the upstream operation, and the echelon multiple used to identify the lot size in the renovation station. Moreover, it identifies the conditions under which the remanufacturing shop will not hold inventory between the two processes, thus renovating all cores immediately after disassembly.

We assume that demand is constant, and the lead time of both processes is zero. We develop the optimal nested policy and perform numerical tests.

Stochastic Process Yield, Deterministic Demand

Consider a remanufacturing shop where the stock of cores is unlimited and freely available for recovery. The recovery process generates remanufactured units of the widget corresponding to these cores. This demand for the remanufactured widget is fairly stable: initially, we consider a constant demand of *D* remanufactured goods per unit time. The recovery procedure includes two stages: a disassembly process and a renovation process. Both operations are costly, require some setup and are subject to a stochastic output yield. The manager has to decide the operating policy that determines the frequency of the two operations (disassembly and renovation) and the size of the respective lots, such that demand is always satisfied at the lowest operating cost. Figure 17 illustrates this scenario in a tire retreading facility.

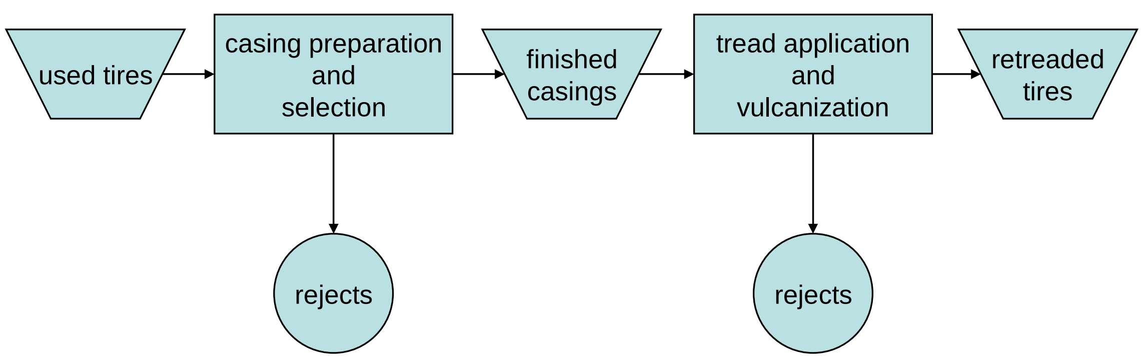

Figure 17. Material Flow in a Tire Retreading Facility

One of the practical problems faced by remanufacturing shops is the constraint in storage space. A large number of used cores arrive at the facility to be processed, but only some of them become re-usable goods. Hence, physical handling may represent a

significant fraction of the holding cost, especially in the earlier stages of the operation. The typical representation of echelon stocking, with nested saw-tooth patterns, represents the value added in each stage. However, this does not completely reflect the importance of physical handling in remanufacturing. Hence, it is useful to identify separately which stage is burdened by the financial and the physical inventory. Figure 18 reflects the two-process environment, where both physical and financial stocks are present in a situation in which there are 3 renovation cycles per disassembly event.

If the remanufacturing operation pays for the cores received at the time of delivery, the financial holding cost lasts until the recovered good is finally delivered to the customer. That is reflected in the downward slope of the financial inventory level in both processes. However, the physical inventory follows a staircase shape in the first process, and a saw-tooth shape in the lower process. That behavior is the same as most other multi-echelon systems. However, the remanufacturing operation is better represented if the two holding costs are treated separately.

In Figure 18, the first station disassembles Q machines, subject to a certain yield, p_d. We propose a nested policy such that the output of the upstream station is split into n equal lots to be processed in the downstream operation. Table 3 shows the notation used in the optimization of this policy.

DISASSEMBLY ECHELON		RENOVATION (REPAIR) ECHELON	
k_d	setup cost of disassembly	k_r	setup cost of renovation
$h_{f,d}$	financial holding cost of disassembled items	$h_{f,r}$	financial holding cost of renovated items
$h_{ph,d}$	physical holding cost of disassembled items	$h_{ph,r}$	physical holding cost of renovated items
p_d	yield of the disassembly operation	p_r	yield of the renovation operation
Q	core disassembly lot-size	n	number of renovation cycles per disassembly event

Table 3. Notation

Costs incurred in the renovation (downstream) process

Considering the yield in the disassembly operation, $p_d\ Q$ ready-to-recover items are available for renovation in the second step. We choose equal lot sizes of $p_d\ Q / n$ cores in each of the next n cycles in the renovation process. If the yield realization in the first renovation cycle is p_r, we have that $p_r\ p_d\ Q / n$ items are produced in the first cycle, which are gradually consumed. Moreover, the renovation cycle lasts $p_r\ p_d\ Q / n\ D$ time units. Hence, the holding costs incurred in the renovation cycle are given by the expressions:

Equation 1. Financial holding cost during renovation cycle: $h_{f,r} \frac{p_d Q}{2n} \frac{p_d p_r Q}{nD}$

Equation 2. Physical holding cost during renovation cycle: $h_{ph,r} \frac{p_d p_r Q}{2n} \frac{p_d p_r Q}{nD}$

There are different reasons driving the yield in each process. Generally, the yield in the renovation process is due to process failures, while the yield in the disassembly process depends on the quality of the incoming material, the used cores. Hence, we may assume that the two yield distributions are not correlated. The setup cost per renovation cycle equals k_r. Therefore, the expected value of the renovation cost per time unit can be expressed as:

Equation 3. $$E\left[\text{renovation cost/time}\right]=\frac{k_r nD}{Q}E\left[\frac{1}{p_d}\right]E\left[\frac{1}{p_r}\right]+\frac{Q}{2n}\left(h_{f,r}E\left[p_d\right]+h_{ph,r}E\left[p_d\right]E\left[p_r\right]\right)$$

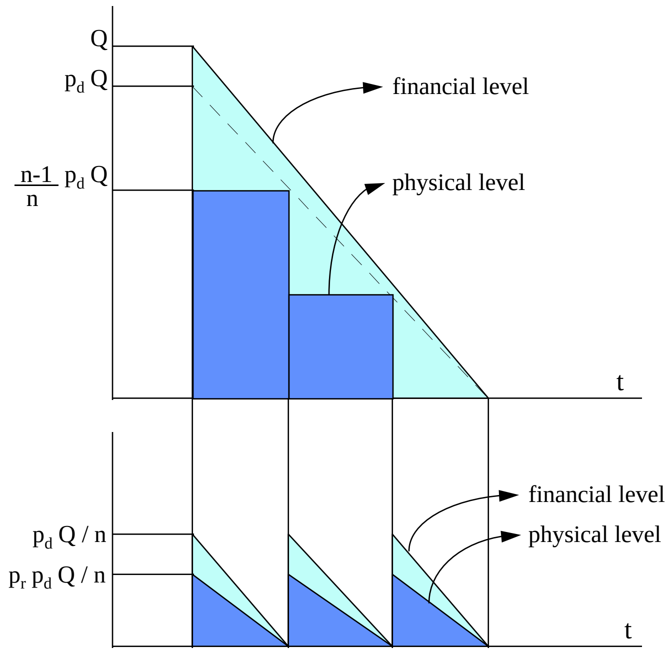

Figure 18. Financial and Physical Level in a Two-process System

Costs incurred in the disassembly (upstream) process

Prior to the renovation process, the used goods inventory is processed and pre-selected during the disassembly process. The duration of the disassembly process depends both on the yield of this operation, as well as on the yield of each subordinate renovation cycle, $p_{r,i}$ (i = 1, … n). Hence,

Equation 4. Disassembly cycle length: $$\frac{p_d Q}{D}\sum_{i=1}^{n}\frac{p_{r,i}}{n}$$

Separating the financial and the physical holding cost, we obtain the expressions:

Equation 5. Financial holding cost during disassembly cycle: $$h_{f,d}\frac{Q}{2}\frac{p_d Q}{D}\sum_{i=1}^{n}\frac{p_{r,i}}{n}$$

Equation 6. Physical holding cost during disassembly cycle: $$h_{ph,d}\frac{n-1}{2n}p_d Q\frac{p_d Q}{D}\sum_{i=1}^{n}\frac{p_{r,i}}{n}$$

The setup cost per disassembly cycle equals k_d. Considering that the yield distributions are not correlated, and that the expected duration of the disassembly cycle is n times longer than the expected duration of the renovation cycle, the expected disassembly cost per time units equals:

Equation 7. $$E\left[\text{disassembly cost/time unit}\right]=\frac{k_d D}{Q}E\left[\frac{1}{p_d}\right]E\left[\frac{1}{p_r}\right]+\frac{Q}{2}\left(h_{f,d}+h_{ph,d}E\left[p_d\right]\frac{n-1}{n}\right)$$

Choice of optimal lot-size at the disassembly process

Equations 3 and 7 provide the closed-form expressions for the relevant inventory costs at each process as a function of the lot-size of the disassembly process (Q) and the number of renovation cycles per disassembly cycle (n). Hence, we can define *K(n)* and *H(n)* as follows:

Equation 8. $$K(n)=(k_d+nk_r)E\left[1/p_d\right]E\left[1/p_r\right]$$

Equation 9. $$H(n)=h_{f,d}+\frac{E\left[p_d\right]}{n}\left(h_{ph,d}(n-1)+h_{f,r}+h_{ph,r}E\left[p_r\right]\right)$$

In addition, we may write in compact form the expected operating cost per unit time as:

Equation 10. $$E\left[C(Q,n)\right]=\frac{DK(n)}{Q}+\frac{QH(n)}{2}$$

Obviously, the expression is convex in Q. For a given value of $n > 0$, the optimal lot-size is:

Equation 11. $$Q^*(n)=\sqrt{\frac{2DK(n)}{H(n)}}$$

and the respective minimum cost is:

Equation 12. $$C^*(n)=\sqrt{2DK(n)H(n)}$$

Now, we have to identify the integer value of n that minimizes this cost expression. It is simple to show that such minimization is equivalent to minimizing *X(n)* given by the expression:

Equation 13. $$X(n)=\frac{E\left[p_d\right]}{n}\left(h_{f,r}-h_{ph,d}+h_{ph,r}E\left[p_r\right]\right)k_d+\left(h_{f,d}+h_{ph,d}E\left[p_d\right]\right)nk_r$$

The value $n_{real}\in R$ that satisfies the first-order condition in the minimization of the *X(n)* expression is:

Equation 14. $$n_{real}=\sqrt{\frac{E\left[p_d\right]\left(h_{f,r}-h_{ph,d}+h_{ph,r}E\left[p_r\right]\right)}{h_{f,d}+h_{ph,d}E\left[p_d\right]}\frac{k_d}{k_r}}$$

The value above is generally not integer. If $n_{real}\le 1$, the minimizing value is $n^* = 1$. Otherwise, we examine two approximations of n_{real}. Define n_{lo} and n_{hi}, integer numbers such that $n_{lo}=\max\left\{n\in\text{Integer Numbers}\,\middle|\,n\le n_{real}\right\}$ and $n_{hi}=n_{lo}+1$.

Clearly, $X(n_{lo}) \le X(n_{hi}) \Rightarrow n^* = n_{lo}$ minimizes the cost function. Otherwise, $n^* = n_{hi}$ is the cost minimizer. Now, we can identify the lot-size at the disassembly process that minimizes the operating cost in the remanufacturing site. It suffices to substitute n^* in the expression for *K(n)* and *H(n)* and, subsequently, substitute them in the expression for *Q*(n)* to solve the cost minimization problem.

Discussion

Equations 11 and 14, combined with the integrality constraint, identify the decision variables that optimize the nested policy suggested for this problem. It gives proper weight to the financial and physical holding costs faced by the remanufacturing firm. Equation 14 shows that the number of renovation cycles is proportional to the ratio between the setup costs of both processes. The same result is observed with the basic two-echelon problem with deterministic production output. Other results are less intuitive: Let the financial holding cost at the disassembly process be relatively low, and the physical holding cost be the same in both processes. In this case, equation 14 may be approximated by the expression

$$\textbf{Equation 15.}\quad n_{real} \approx \sqrt{\left(\frac{h_f}{h_{ph}} - 1 + E[p_r]\right)\frac{k_d}{k_r}}$$

where h_f is the financial holding cost, incurred at the renovation process only, and h_{ph} is the physical holding cost, of the same magnitude in both processes. Hence,

- The number of renovation cycles increases with the financial cost of the remanufacturing operation. This happens because by increasing the number of cycles, the size of finished goods inventory reduces, which drives the financial holding cost.
- The number of renovation cycles decreases with the physical handling cost. This is an indirect effect. Increasing the number of renovation cycles implicitly reduces the lot-size in the disassembly process, hence, reducing the physical holding cost at this level.
- If the expected renovation yield is low, and the physical holding cost is relatively high, there will be as many renovation cycles as disassembly cycles. This happens if the expression inside the square root is less than 1 (or even negative), implying that $n^* = 1$.

The last effect clarifies why, in some remanufacturing operations, the manager chooses not to hold inventory between the two events. In these environments, once the lot of used goods is disassembled, it proceeds immediately to the renovation area. This behavior is justifiable because handling an excessive stock of disassembled goods may be quite problematic if storage space is at a premium. However, if physical handling is not costly, it is likely that the renovation station will process smaller lots than the disassembly station.

Example

A remanufacturing facility faces an annual demand of 600 units of a certain electric motor series. The facility has access to an ample supply of used motors to repair at a small cost. Holding costs have been estimated as $h_{f,d} = 0.5$, $h_{f,r} = 4$, $h_{ph,d} = h_{ph,r} = 2$. Moreover, ordering and setup costs have been estimated as $k_d = 30$ and $k_r = 6$. Pre-inspection yield for

each lot is uniformly distributed between 0.5 and 0.95. Final inspection yield is also uniformly distributed—between 0.75 and 0.95. Under these conditions, we find that $n_{lo} = 2$ and $n_{hi} = 3$. Since $X(3) = 61.9 < 63.6 = X(2)$, we conclude that $n^* = 3$. Hence, $K(3) = 80.9$ and $H(3) = 2.84$, leading to $Q(3) = 185$; and expected inventory management cost is minimized at $C(3) = 525$. The following graph shows the expected inventory costs at different (Q, n) combinations.

Figure 3 illustrates that the operating cost does not change significantly close to the optimal value solution (185, 3). The cost increase for erring in just one dimension (either lot size or number of renovation cycles) is quite minor, but simultaneous errors in both dimensions can easily increase operating costs by 50% or more. Consequently, the remanufacturing facility must be careful deciding the inventory policy associated with its production process to ensure that the operating cost is remains close to its theoretical optimum.

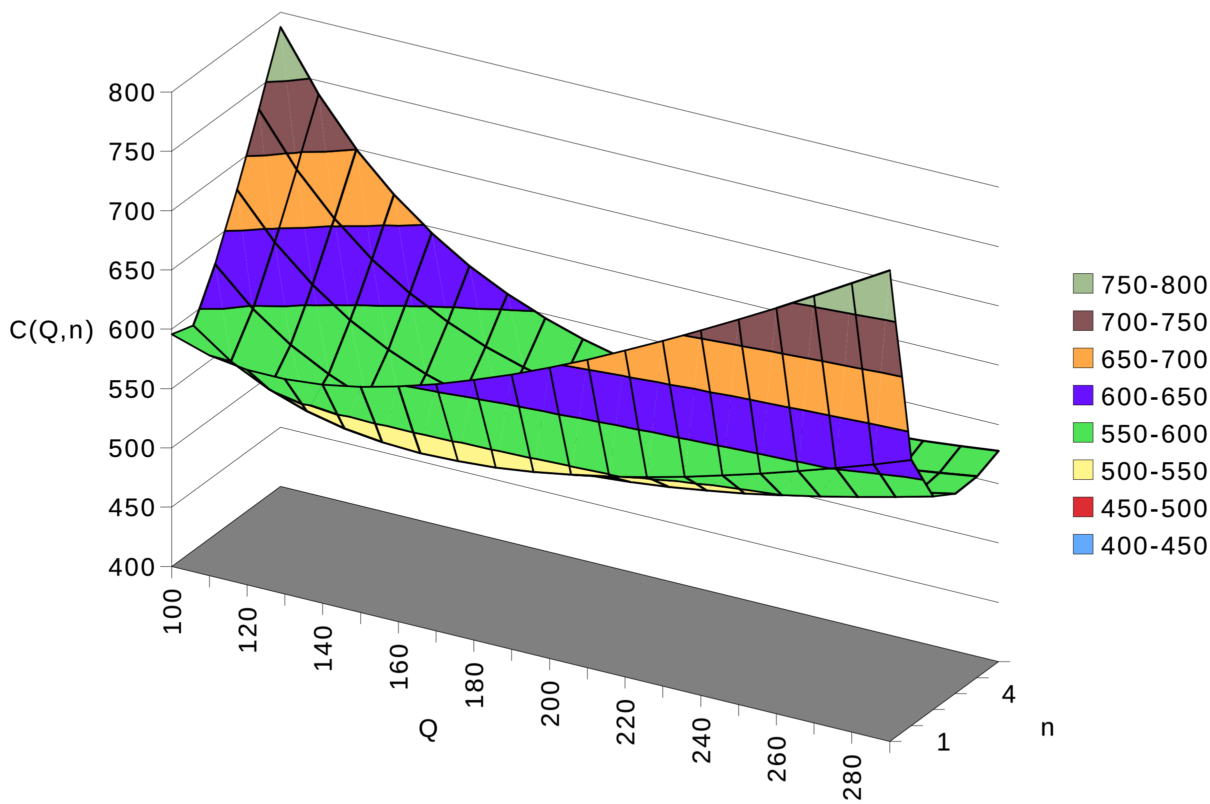

Figure 3. Expected Inventory Costs at Different (*Q, n*) Combinations

Conclusion

We have proposed an inventory policy for multi-echelon remanufacturing operations in which the first echelon corresponds to the product disassembly and sorting operations, and the second echelon corresponds to the repair, renovation and final inspection operations. The separation between these two sets of operations is important because they present sizable yield, affecting the holding cost at each level of the process. We find a simple inventory policy built upon the familiar structure of the economic order quantity, leading to the optimal disassembly lot size and the number of renovation cycles per disassembly event.

This policy is useful in DoD depots, where large remanufacturing programs are engaged periodically for the recovery of valuable durable assets. We intend to extend this study by testing the policy provided herein in actual remanufacturing operations in the DoD.

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B2B Models for DoD Acquisition

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Abstract

A central vision of B2B e-commerce is that of an electronic marketplace that would bring suppliers with major buyers of goods and services for the purpose of conducting "frictionless" commerce. The hope is that these suppliers would compete on price, transactions would be automated and low cost, and as a result, the price of goods and services would fall. Numerous Internet marketplaces came into being during the Internet boom; however, an almost equal number disappeared following the Internet bubble burst. Still, many survive today based on a variety of models that are quite successful. If a right model is selected, it could help large organizations, like the DoD, achieve great efficiencies for their acquisition and procurement processes.

The objective of the paper is to examine models for classifying and differentiating the business functionality provided by Internet marketplaces and to investigate the impact of the various models on government and DoD acquisition. The models will consider such variables as types of goods and services purchased, how these goods and services are purchased, pricing mechanisms, the characteristics of the markets, and ownership of marketplace.

Introduction

Business-to-business (B2B) e-commerce refers to transactions between businesses conducted electronically over the Internet, intranets, extranets, or private networks. Such transactions may be conducted between a business and its suppliers or between a business and any other business.

It is estimated that in 2003, B2B e-commerce in the United States was a $1.5 trillion business. This represents about 11% of the total B2B trade estimated at $13.5 trillion (Laudon & Traver, 2004). Gartner group predicts this percentage to grow steadily to reach over 40% in 2010. Forrester's research predicts a higher percentage of 53%.

There are many potential benefits of B2B e-commerce. These benefits depend on the model used, but are thought to include the following:

- Significant cuts in acquisition cost
- Expediting cycle-time
- Reducing errors and improving quality of service
- Seamless integration with suppliers
- Ability to have purchasing data instantly
- Reducing inventory levels and costs
- Immediate response to changes in customer purchasing patterns
- Facilitating mass customization
- Increasing opportunities of collaboration between buyers and sellers

In this paper, we examine models for classifying and differentiating the business functionality provided by B2B e-commerce and examine the impact of the various models on government and DoD acquisition. The models will consider such variables as types of goods and services purchased, how these goods and services are purchased, pricing mechanisms, the characteristics of the markets, and ownership of marketplace.

B2B Characteristics

There are many ways to characterize B2B transactions. In this paper, we differentiate between different types of B2B transactions based on the following characteristics: Parties to the transaction, types of transactions, types of products and services procured, the direction of trade, and number and form of participation.

Parties to the Transaction

B2B commerce can be conducted *directly* between a buyer and seller or through a third-party intermediary.

Types of Transactions

There are two types of transactions: Spot purchases and long-term sourcing. Spot purchases refer to the purchasing of goods and services as they are needed at the prevailing market prices. Long-term sourcing refers to purchases made through long-term contracting agreements that are negotiated between the buyers and the sellers.

Types of Products and Services

There are two types of Products and Services: Direct and Indirect. Direct products and services are used directly in making the product, such as wood in furniture or paper in a book. Direct products and services are usually purchased in large quantities using long-term sourcing. Indirect products and services (such computer equipments, lights, or tools) support production, but are not directly involved in creating the end product. They are usually referred to as maintenance, repairs, and operations (MROs).

Direction of Transactions

B2B transactions can be classified as either vertical or horizontal. A vertical market is one that provides products and services for a specific industry. Examples include cars, steel, or electronics. Horizontal markets refer to markets that serve many different industries. Examples are office supplies, computers, and tools.

Number and Form of Participation

There are four types of electronic marketplace participation: 1) Sell-side, 2) Buy-side, 3) Exchanges, and 4) Collaborative commerce.

In sell-side commerce, there is one seller that does all the selling to many buyers. In buy-side commerce, there is one buyer that does all the buying from many sellers. Both types are collectively referred to as company-centric electronic commerce, because they address a single company buying or selling needs.

Exchanges are many-to-many electronic marketplaces, where many buyers and many sellers meet in electronic markets to conduct business transactions. Exchanges are usually owned and managed by a third party or by a consortium, and are open to all interested parties, and are, thus, considered public electronic marketplaces.

Collaborative commerce goes beyond selling and buying activities and includes activities that represent more than financial transactions—such as communication and sharing of information, planning, design, manufacturing, and management. Collaborative commerce is relationship-based rather than transactions-based and bears resemblance to internal workgroup collaborative environments.

Buy-side Electronic Marketplaces Models

Under these models, a buyer opens an electronic marketplace on its own servers and invites potential suppliers to bid on the products and services that the buyer needs. This invitation could take the form of: 1) a request for Quote (RFQ), or 2) an invitation for a reverse auction. An example of the former is FedBizOpps (2007) and GSA e-buy (2007). An example of the latter is NAVSUP NavyAuctions (2007).

FedBizOpps is the single government point-of-entry (GPE) for Federal government procurement opportunities over $25,000. Government buyers are able to publicize their business opportunities by posting information directly to FedBizOpps via the Internet. Using the same portal, commercial vendors seeking Federal markets for their products and services can search, monitor and retrieve opportunities solicited by the entire Federal contracting community.

E-buy is an electronic Request for Quote (RFQ)/Request for Proposal (RFP) system designed to allow Federal buyers to request information, find sources, and prepare RFQs/RFPs, online, for millions of services and products offered through GSA's Multiple Award Schedule (MAS) and Government-wide Acquisition Contracts (GWAC).

Navy Auctions is a secured Internet portal that allows online suppliers to compete in real-time for contracts by lowering their prices as they see other offers. In its first reverse auction, the Navy estimates that they achieved savings of 28.9% over the historical price for these items. The auction lasted 51 minutes, and the contract, valued at $2.375 million, was awarded within an hour of the reverse auction closing.

B2B Exchanges

As discussed earlier, exchanges are electronic marketplaces where many buyers and sellers meet to buy and sell goods and services. Exchanges are known under different names: e-marketplaces, e-markets, Internet exchanges, Net marketplaces, and B2B portals.

Classification of Exchanges

There are numerous ways of classifying exchanges. We use an approach similar to that suggested by Kaplan and Sawhney (2000) and Kerrigan, Roegner, Swinford and Zawada (2001). The classification model consists of a 2x2 matrix, as shown in Figure 1. The x-axis represents the types of goods and services purchased (indirect goods vs. direct goods), and the y-axis represents how these goods and services are purchased (spot purchases vs. long-term contractual agreement). The intersection of these dimensions produces four cells representing four types of exchanges: Horizontal exchanges (also known as e-distributors), horizontal distributors (also known as e-procurement), vertical exchanges (also known as independent exchanges), and vertical distributors (also known as industry consortia). Each of these exchanges seeks to provide value to customers in different ways. We discuss each type of exchange in more detail in the following sections.

		What Organizations Buy	
		Indirect Goods and Services (MROs)	Direct Goods and Services
How Organizations Buy	Spot Purchasing	**Horizontal Exchanges (E-Distributors)**	**Vertical Exchanges (Independent Exchanges)**
	Long-term Sourcing	**Horizontal Distributors (E-Procurement)**	**Vertical Distributors (Industry Consortia)**
		Horizontal Markets ⇔	Vertical Markets

Figure 1. Types of Internet Marketplaces

Horizontal Exchanges

Horizontal exchanges are independently owned intermediaries that offer individual customers a single source from which to make spot purchases of indirect or MRO goods. They operate in a horizontal market that serves many different industries with products from many different suppliers. Horizontal exchanges are usually “public” markets that any firm can participate in. They usually charge fixed prices, and their owners make money by charging a markup on products they distribute. The primary benefits to customers are lower search costs, lower transaction costs, wide selection, rapid delivery, and low prices. An example of a horizontal exchange is Grainger (2007) and the DoD Emall (2007).

The DoD Emall was launched by the Defense Logistics Agency (DLA) in 1998 as the DLA Emall. It was created to leverage purchasing power across agencies to provide the Military

Services and other Federal Government Agencies with volume discounts from Military and Commercial suppliers. Its mission is indicated in the FY99 *DoD Authorization Act* which states, “the Joint Electronic Commerce Program Office of the Department of Defense shall develop a single, defense-wide electronic mall system, which shall provide a single, defense-wide electronic point of entry and a single view, access, and ordering capability for all Department of Defense electronic catalogs.” DLA was named the executive agent for the DoD Emall, which remains dedicated to its DoD-wide mission.

There are currently over 28,000 user accounts on the DoD Emall with 500 new users added each week. These users represent the DoD (All Services, National Guard, Reserves) as well as other Federal Agencies (DHS, FBI, etc.). More than 850 Commercial Contracts are currently hosted on DoD Emall, with additional catalogs added weekly. The DoD Emall has shown tremendous growth—with a sales increase from $14M in FY02 to $336M through April of FY05.

Horizontal Distributors

Similar to horizontal exchanges, horizontal distributors are independently owned intermediaries connecting hundreds of online suppliers offering millions of MRO goods to thousands of business firms. They differ from horizontal exchanges in that they operate in a horizontal market in which long-term contractual purchasing agreements are used to buy indirect goods. Another important difference is that horizontal distributors usually provide value-chain management services, which could include the automation of a firm’s entire procurement process on the buyer side and the automation of the selling business processes on the seller side. For buyers, this includes the automation of purchase orders, requisitions, invoicing, and payments. For suppliers, it includes the automation of catalog creation, content management, order management, order fulfillment, invoicing and shipment. Horizontal distributors make money by charging a percentage of each transaction, licensing consulting services and software, and assessing network use fees.

The two largest horizontal distributor players are Ariba (2007) and Perfect Commerce, previously CommerceOne (2007). Although some Government and DoD initiatives include some characteristics of this model (e.g., e-buy), there is no Government or DoD effort that provides a full automation of the acquisition process on the buyer side and the automation of the selling process on the seller side.

Vertical Exchanges

Vertical exchanges are independently owned online marketplaces that connect hundreds of suppliers to potentially thousands of buyers in a dynamic real-time environment. They are typically vertical markets in which spot purchases can be made for direct inputs (both goods and services). Similar to horizontal exchanges, the benefits for buyers include reduced search costs and lower prices, while the benefits for sellers include access to the global purchasing environment and opportunity to unload production overruns. Vertical exchanges make money by charging a commission on each transaction; pricing can be through an online negotiation, auction, RFQ, or fixed prices. Vertical exchanges are “public” markets and are biased in favor of the buyer. An important measure of success for vertical exchanges is their liquidity—which is a measured by the numbers of buyers and sellers in the market, the volume of transactions, and the size of transactions. If there is a small number of participants, a low volume of small transactions, an exchange usually fails.

Examples of Vertical Exchanges include E-steel (2006), a spot market for steel products and Foodtrader (2003), a spot market for the food-products industry.

Vertical Distributors

Vertical distributors, also known as industry consortia, are industry-owned vertical markets in which long-term contractual purchases of direct inputs can be made from a limited set of invited participants. They serve to reduce supply-chain inefficiencies by unifying the supply chain for an industry through a common network and computing platform. They make money through: 1) Industry members who pay for the creation of the site and contribute initial operating capital and 2) Buyer firms who pay transaction and subscription fees. The pricing mechanism of this model ranges from auctions to fixed prices to RFQs. The bias of industry consortia is toward large buyers who benefit from competitive pricing. Benefit to suppliers is from access to large-buyer-firm procurement systems, long-term stable relationships, and large-order sizes.

There are numerous vertical distributors in many industries, with many industries having more than one. The industries with the most common consortia are metals, chemicals, and retail. The long-term viability of Vertical Distributors is yet to be seen.

Examples of Vertical Distributors are Covisint (2007) for the automotive industry and Exostar (2007) for Defense and Aerospace.

How Are Exchanges Evolving?

Exchanges' capabilities are evolving rapidly and growing increasingly sophisticated. Figure 2 depicts some of these changes. Horizontal exchanges are moving away from being simple electronic marketplaces toward more active and sustained relationships with buyer companies by providing added-value services and participating in industry consortia as suppliers of indirect goods. These added-value services include the automation of part or the entire procurement process on the buyer side and the automation of the selling business processes on the seller side. For example, selling value-added services could include Web store fronts, the ability to configure and price products, and customer support, such as order-status monitoring, demand planning and collaboration.

Similarly, vertical exchanges are being absorbed into industry consortia as many were not attracting enough players to achieve liquidity. Another important trend in exchanges is the movement from simple transactions of spot purchases to longer-term sourcing agreements involving both direct and indirect goods (Wise & Morrison, 2000).

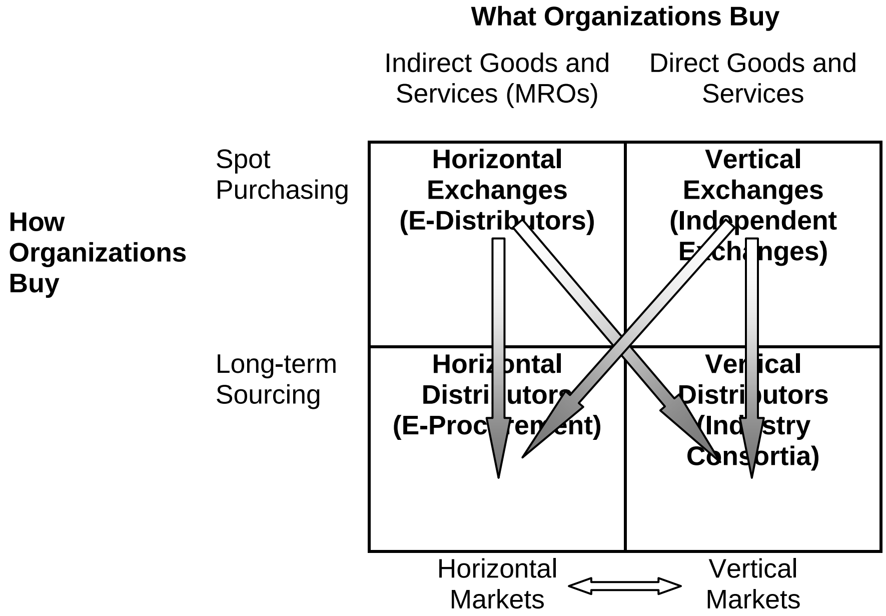

Figure 2. Evolution of Exchanges

Collaborative Commerce

Collaborative commerce is used to describe Web-based communication environments that extend beyond procurement to include coordinating trans-organizational business processes. Collaborative Commerce permits buyer firms and principle suppliers to share product design and development, marketing, inventory, production scheduling, and unstructured communications. It generally starts as an enterprise resource planning (ERP) system in a single firm that is then expanded to include the firm's major suppliers. This fact differentiates private industrial networks from consortia, which are usually owned collectively by major firms through equity participation. Collaborative commerce is considered a buyer-side solution with buyer biases. It is the most prevalent form of Internet-based B2B.

A good example of the benefits of collaborative commerce is its collaborative resource planning, forecasting, and replenishment (CPFR)—which require the collaborating members to forecast demand, develop production scheduling plans, coordinate shipping, warehousing, and replenishment activities to ensure retail and warehouse shelf spaces are replenished "just in time." This approach could potentially realize hundreds of millions of dollars in excess inventory and production savings and, therefore, produce large benefits to justify the cost of developing the collaboration network.

A second example of collaborative commerce is demand-chain visibility, in which excess capacity and supplies in the supply-and-distribution chain is visible to all members of the chain. Adjustments could then be made in real-time to production capacities to avoid excess inventories that usually create pressure to discount merchandise, reducing profits to all parties involved.

Collaborative commerce faces many implementation barriers. First, participating firms are required to share sensitive data with their business partners. This is a particularly major impediment for government and DoD organizations. Second, integrating collaborative networks into existing ERP systems and EDI networks is expensive and time-consuming. Third,

collaborative commerce requires a change in mind-set and behavior of employees, which constitutes a major paradigm shift.

Conclusions

While B2B e-commerce today accounts for a small percentage of the total B2B, it is growing steadily and expected to reach 40% – 50% of the total B2B trade in a few years. B2B transactions promise to help organizations run more efficiently by achieving significant cost savings and reductions in cycle-time.

Many models of B2B e-commerce have emerged, each providing different functionality for the business it supports. Initially, B2B models' focus was commerce and transaction execution. However, newer models' focus is increasingly on value-added services and support for cross-enterprise collaboration. It is important for the DoD to examine these models, their characteristics, and trends in order to leverage the future of B2B and, therefore, to do business more efficiently.

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